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STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

BRADLEY — State Mineralogist

APRIL 1943 — No. 2

ALIFORNIA JOURNAL

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QUARTERLY CHAPTER
OF
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FERRY BUILDING, SAN FRANCISCO
CALIFORNIA

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DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

WALTER W. BRADLEY State Mineralogist

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STATE MINERALOGIST'S REPORT XXXIX

STATE DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO
CALIFORNIA

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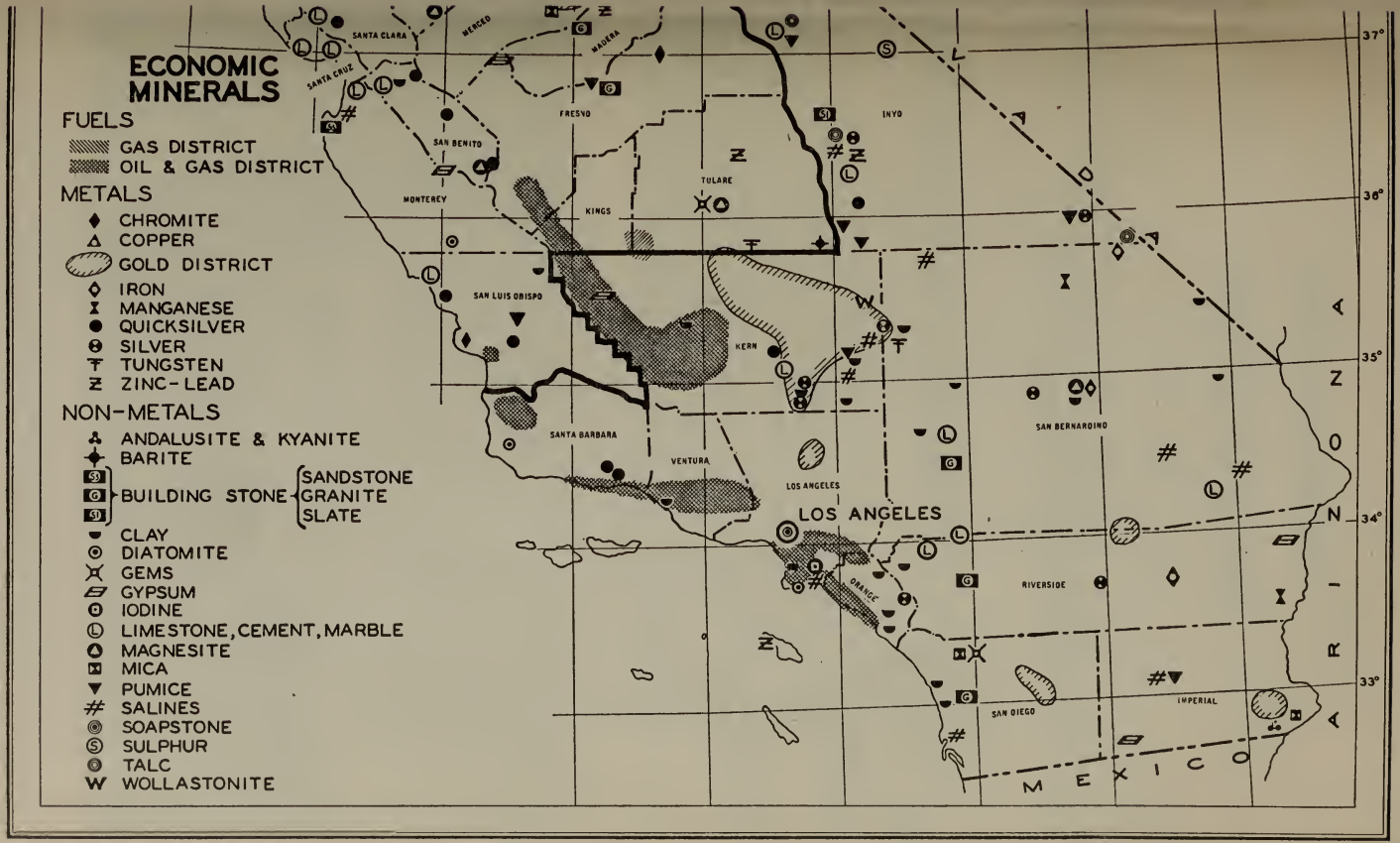
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ADMINISTRATION

ADMINISTRATIVE REPORT

By Walter W. Bradley, State Mineralogist

Personnel

In April, Mr. John G. Bongard, ore-buyers license inspector, took military leave from the Division of Mines and entered war service in the 'Sea Bees' (Construction Battalions, U. S. Navy).

New Publications

Since last noted, the following publications of the Division of Mines have been received from the State Printer and are now available at the offices of the Division:

CALIFORNIA JOURNAL OF MINES AND GEOLOGY

January 1942, being Chapter 1 of State Mineralogist's Report XXXVIII. This chapter contains *Mines and Mineral Resources of Sierra County;* also a special article, *Chromium.* Price 60 cents (plus sales tax in California).

April 1942, being Chapter 2 of State Mineralogist's Report XXXVIII, containing: *Mineral Resources of Imperial County; Geology and Mineral Deposits of the Cargo Muchacho Mountains, Imperial County;* special articles on *Imperial Carbon Dioxide Gas Field, The Legendary 'White Metal' and its 'Ore,' Mine Assessment Work Suspended on Claims within Withdrawn Areas; Summary of 1941 Mineral Production of California.* Price 60 cents (plus sales tax in California).

July and October 1942 (combined), being Chapters 3 and 4 of State Mineralogist's Report XXXVIII and containing: *Hot Springs Deposits of the Coso Mountains; Contact Metamorphic Rocks of the Twin Lakes Region, Fresno County; Tungsten Deposits of the Confidence Mining District, Tuolumne County; Geology of the Welsh Tungsten Deposits, Madera County; Ghost Canyon Tungsten Claims, Madera County; Tabulation of Tungsten Deposits of California to Accompany Economic Mineral Map No. 4* (which is enclosed in pocket; and which is also available for separate sale). Under special articles: *Biennial Report of the State Mineralogist.* This chapter also carries the Index for Volume XXXVIII. Price $1.20 (plus sales tax in California).

BULLETIN 118, GEOLOGIC FORMATIONS AND ECONOMIC DEVELOPMENT OF THE OIL AND GAS FIELDS OF CALIFORNIA. Paper-covered preprints now available, including in pocket, Outline Geologic Map of California, Showing Oil and Gas Fields and Drilled Areas, scale 1:1,000,000. Price $4.00 (plus sales tax in California). The cloth-bound volume will be available at an early date, later, price $6.00 (plus sales tax). The map (Economic Series No. 2) is also available for separate sale, at $1.00 (plus sales tax in California).

SAN FRANCISCO FIELD DISTRICT

MANGANESE DISCOVERY IN SAN MATEO COUNTY

By Henry G. Hubbard*

Redwood Material Company's Quarry. This deposit is at Ralston Avenue, Belmont, between the Bayshore Highway and the Southern Pacific Railroad adjacent to the Coast Highway, in T. 5 S., R. 4 W., M. D. A vein strikes north in the small hill now being quarried for road-building material. The dip is 45° E. and the width is reported to be four feet. The vein extends for a distance of 300 feet along the quarry floor. Much of it is covered by loose dirt.

Considerable silica accompanies the manganese oxides observed in place, but several tons of ore on the dump showed bunches of the high-grade oxides psilomelane and pyrolusite. The hill being quarried and a small area surrounding it consists of typical Franciscan rocks and there is a large tonnage of clay colored by iron oxides. This clay is not strictly an ocherous limonite but it has possible value as a camouflage material.

The quarry is owned in fee by Redwood Material Company, Maple Street, Redwood City, California. President C. B. Stoner contemplates opening the manganese vein formerly exposed in the quarry floor and bulldozing an opencut to a depth of 10 or 15 feet.

* Junior Mining Engineer, Division of Mines. Manuscript submitted for publication May 14, 1943.

Fig. 1. Low-grade remnant of manganese ore lens at Redwood Material Company's quarry. Some high-grade appears on dump in background.

LOS ANGELES FIELD DISTRICT

CURRENT MINING ACTIVITY IN SOUTHERN CALIFORNIA

By W. B. Tucker* and R. J. Sampson**

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IMPERIAL COUNTY

Whedon Manganese Mines, Inc. (*Tolbard, Everharty, Tres Amigos Groups*). These mines, comprising 28 claims, are in secs. 18 and 19, T. 11 S., R. 21 E., S. B., 4 miles east of Midway Well. The owner is V. B. Whedon, Bank of America Building, Beverly Hills, California.

These properties have been consolidated by this company which has had them in continuous operation for about a year. Shipments aggregating 45 cars have been made largely to the Phoenix stock pile of the Metals Reserve Company.

Twenty men are working.

Bibl.: State Mineralogist's Reports XXII, pp. 264-266; XXXVIII, p. 130; U. S. G. S. Bull. 710E.

INYO COUNTY

Bishop Tungsten Company. Ralph H. Moore is manager. The company has ceased operations and will probably dispose of its mill at Bishop. This company operated successfully for several years. During this period some 68,000 tons of ore was milled.

Bibl.: State Mineralogist's Reports XXXIV, pp. 462-463; XXXVII, pp. 292-293; U. S. G. S. Bull 640, pp. 229-255.

Imperial Metals, Inc. (*Defiance, Independence,* and *Thompson Mines*). S. B. Mosher, 811 West Seventh Street, Los Angeles, is president. The company is shipping from the Defiance, Independence, and Thompson properties at Darwin.

The 250-ton mill which was completed last year is temporarily shut down pending adjustments designed to increase the recovery of the tungsten in the lead ores. Shipments of 5 to 7 cars per week are being made.

Approximately 35 men are employed.

Bibl.: State Mineralogist's Reports VIII, p. 226; X, p. 211; XV, p. 98; XVII, pp. 287-288; XXII, p. 483, 486, 487; XXXIV, pp. 436-437 and 557-560; XXXVII, pp. 567-568; Reports of Director of the Mint, Precious Metals in U. S., 1883, p. 164; 1884, p. 103; U. S. G. S. Bull. 580, pp. 14-15.

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* District Mining Engineer, Division of Mines.
** Assistant District Mining Engineer, Division of Mines. Manuscript submitted for publication April 16, 1943.

Lakeview Tungsten Mine. The Lakeview mine, comprising 7 claims, is on the south slope of Mount Tom, probably in sec. 27, T. 7 S., R. 30 E., M. D., about 20 miles by road west of Bishop; elevation 10,700 to 11,000 feet. Owners are P. W. Carpenter, George Brown, and W. Bemis Phelps, of Bishop, California. The property is under lease and option to James E. Babcock, 112 West Ninth Street, Los Angeles. G. A. Joslin is consulting engineer.

The country rocks are dolomitic limestone and granite. The ore occurs in tactite which marks the contact of these two formations. The scheelite is disseminated through an epidote-garnet-quartz gangue. The tactite is some 50 feet wide, and has a mineralized core which averages about 12 feet in width. The strike is N. 10° W., the dip 80° W. to vertical. The mineralized zone has been proved on the surface for a length of 125 feet. Samples contain from 1 to 29 percent WO_3; 75 tons of ore milled in Bishop averaged over 4 percent.

Development consists of open cuts and a shaft 50 feet deep. Due to climatic conditions, work has been suspended until the spring of 1943.

Pacific Tungsten Company. E. L. Cord, Beverly Hills, California, is president and owner. The company has been operating the Durham, Fernando, and St. Charles mines at Darwin, and milling the ore in the West Coast Tungsten Company's mill near Keeler.

Operations have been suspended at these properties with the exception of a new shaft which is being sunk on the Fernando.

Bibl.: State Mineralogist's Reports XXII, pp. 484-485; XXXIV, pp. 440, 560-561; XXXVII, pp. 570-571.

The Panaminas Company. George W. Tower, 230 Park Avenue, New York, N. Y. is managing director. The company has a bond and lease on the Adamson tungsten deposit which consists of 8 claims, in sec. 34, T. 6 S., R. 30 E., M. D., in the head of Morgan Creek, about 21 miles west of Bishop and adjoining the Pine Creek mine of the U. S. Vanadium Company on the north; elevation 11,500 feet to 12,800 feet. The owner is Don B. Adamson of Bishop, California. A. H. Heller, 650 South Grand Avenue, Los Angeles, is manager, and Frank Merrilees, Bishop, is superintendent of this operation.

On this property, five roughly parallel veins have been discovered. Each occurs in tactite at the contact of granite and a limestone pendant. The general strike is north, the dip 75° to 80° E., although at and near the surface, the dip is westerly. The veins are known as the Camp vein, Vanadium vein (a continuation of the U. S. Vanadium vein), Middle vein, East vein, and Northwest vein. The East vein is said to be 75 feet wide; for a distance of 200 feet along the outcrop, it carries 2.5 percent WO_3. The Middle vein, about 50 feet west of the East vein, is 15 feet wide, and for a distance of 400 feet carries 1.25 percent WO_3. The Vanadium vein is about 1000 feet west of the Middle vein. The Camp vein is 50 feet farther west. It is 12 to 15 feet wide and contains 1 percent WO_3. The Northwest vein is about 15 feet wide, containing 1 percent WO_3. The gangue is epidote and garnet, through which scheelite is disseminated.

Development work consists of a tunnel on the Camp vein and one being driven under the Northwest vein; also, a crosscut tunnel has been started which will tap both the Middle and East veins. As yet, none of

these tunnels have any great length but they are being driven ahead daily.

This company has spent a large sum of money in preparing the property for development and operation. A road has been built to the property and a camp constructed, all units of which are connected by completely covered snowsheds.

Equipment consists of 1500-cubic-foot compressor and a 500-cubic-foot portable machine, bulldozers and snow plows. Four mucking machines are in use in the headings. Storage-battery locomotives are used for haulage. Construction of a jig-back tram 2000 feet long has been started, and the material for a gravity tram one mile long is on the ground. The long tram will terminate at the U. S. Vanadium Company's mine bins. Southern Sierras Company supplies the power.

Ore from development work is going to a stock pile on the property. Seventy-five men are employed.

Bibl.: State Mineralogist's Reports XXXIV, p. 462; XXXVII, pp. 292-293.

Shoshone Mines, Inc. (see also *Tecopa Consolidated Mines*). George W. Nilsson, 555 South Flower Street, Los Angeles, is secretary, and W. Buford Davis, Tecopa, California, president and manager. This company leased the Noonday and Gunsite mines, some 7 miles east of Tecopa, starting its operation in February 1940.

For a description of these properties and history of past operations, the reader is referred to the bibliography given under the Tecopa Consolidated Mines, herein.

The Gunsite-Noonday fissure has been faulted near the south end of the Noonday mine. This fault strikes northeast and has displaced the vein 1200 feet. The present company is working the segment which is 1200 feet southwest of the former Noonday workings, on the Columbia No. 2 claim. Here the vein is 8 to 14 feet wide. The ore shoot is more than 200 feet in length. Gold, silver and lead average better than $25.00 per ton.

New development consists of a shaft sunk on 30° inclination 630 feet, with levels at 165, 265, 365 and 465 feet. Shipments of one car per week are made to the smelter.

Thirty men are employed.

Tecopa Consolidated Mines. Dr. L. D. Godshall, 722 South Oxford Avenue, Los Angeles, is president. The company has leased its Noonday and Gunsite mines to Shoshone Mines, Inc., George W. Nilsson, secretary, 555 South Flower Street, Los Angeles. W. Buford Davis, at Tecopa, is manager.

Bibl.: State Mineralogist's Reports XV, pp. 95-96; 103-104; XVII. pp. 286-287; 291-293; XXII, p. 485; 491-492; 503-504; Rept. of Director of the Mint, Precious Metals in the U. S., 1883, p. 166.

Utacala Group (Zinc Hill Mine). The Utacala group comprises 12 claims in the Darwin district on Zinc Hill, 9 miles east of Darwin; elevation 4000 feet. The property has been acquired by Combined Metals Production Company, E. H. Snyder, president, Feldt Building, Salt Lake City, Utah; Guy H. Herbert, Jr., is superintendent.

This company has been developing the property for more than a year and they are now shipping 4 to 5 cars of zinc-sulphide ore per week to their mill at Bauer, Utah.

Bibl.: State Mineralogist's Reports XVII, pp. 294-295; XXII, p. 503; XXIV, p. 458.

KERN COUNTY

Cow Canyon Group. This group of 8 claims is 2½ miles east of Walker's Pass Road and about 3 miles from Dee's Service Station, probably in sec. 12, T 25 S., R. 36 E., M. D.; owners are A. N. Houser, of Weldon, California, W. P. Lewis, of Trona, California, and W. J. Betty, of Inyokern, California. The property was leased to H. V. Hughes.

The lessee had a crew of 14 men trenching the tactite outcrops for 30 days, at the end of which time he relinquished the property.

F. O. B. Tungsten Group. This group of 22 claims is on the west side of Indian Wells Canyon, 5½ miles west of the Owens Valley highway and approximately the same distance from the Homestead Service Station, which is 19 miles south of Little Lake; elevation is about 5000 feet. Owners are Grant P. Merrill, Mojave, California, and A. L. Crowthers, Bishop, California. This property is leased to Erle P. Halliburton, 1709 West Eighth Street, Los Angeles.

The county rock, as indicated by very limited outcrops, consists of gneissoid granite and crystalline limestone. The limestone appears to have a thickness of 100 feet or less. The contacts are marked by silicate zones, consisting largely of epidote and garnet. These zones are as much as 12 feet in width and probably average about 6 feet. They are traceable along the mountainside for nearly 1200 feet. There are two parallel veins striking northwest and dipping steeply to the east. Each occurs on the limestone side of the silicate zone and the scheelite is associated with a light-pink garnet. This pink garnet occurs only in very small crystals, whereas some of the associated scheelite crystals are more than an inch across. A northeast-trending fault has displaced the veins approximately 150 feet at a point about 300 feet from the northwest end of the deposits. It is reported that samples from the outcrop run from 2½ percent to 12 percent, averaging 3 percent.

The lessee is trenching this hillside to determine the extent of the deposit.

Equipment consists of portable compressor and jackhammers. Four to six men are working.

Hi-Peak Tungsten Group. The 14 claims of this group are on the east slope of the Sierra Nevada, about 19 miles south of Little Lake and one mile west of the Owens Valley highway, in sec. 10, T. 26 S., R. 28 E., M. D. Owners are Emery V. Bales and H. U. Gifford. The property is leased to U. S. Flare Corporation, J. M. Hoyt, Jr., president, 9730 Wilshire Boulevard, Beverly Hills, California, and Norman Whitmore, consulting engineer, Subway Terminal Building, Los Angeles.

The country rocks are granite and crystalline limestone. The limestone apparently has been intruded by a series of narrow, granitic dikes which are now schistose. The veins, of which some 6 or 8 have been found on the property, occur at or near the contacts, striking north and dipping about 70° E. As now exposed, they are from 5 to 8 feet, between walls. The vein filling is largely altered wall rock but on one or both walls there is usually a streak 6 to 8 inches, principally epidote, which is plentifully sprinkled with scheelite. Scheelite is sparsely disseminated throughout the adjoining 2 feet. This

scheelite fluoresces a golden color, but it is said that the molybdenum content is low.

Development consists of two tunnels. The upper tunnel driven southwest 280 feet, was in granite for about 120 feet, then passed into alternations of tactite and granitic schist without encountering ore. About 100 feet below and several hundred feet north, another crosscut tunnel has been driven west 300 feet. While most of the rock in this tunnel is limestone, there are narrow, granite-schist dikes at infrequent intervals. Three veins have been encountered in the lower tunnel; the first at 92 feet, the second at 134 feet, and the third at 198 feet from the portal. The walls of the first and third are limestone and schist but the second vein appears to be wholly in limestone. Drifts have been driven on these veins as follows: first, north 60 feet, raise 25 feet; second, south 100 feet, raise 33 feet; third, north 18 feet. The 250 tons of ore shipped from these workings are said to have averaged about 1 percent WO_3.

Equipment consists of 115-cubic-foot and 210-cubic-foot compressors. Six men and D. B. Christison, superintendent, are employed.

Rand Gold Dredging Associates. Newton Cleaveland, Capt. Norman Cleaveland, Mayville C. Milton, and F. P. Adams, of 315 Montgomery Street, San Francisco, have leased 1000 acres about 2 miles west of Randsburg from various owners. M. E. Powers is in charge of operations on the ground.

A 3½-cubic-foot, 3000-yard-capacity bucket dredge has been moved onto this ground from the property of the Roaring River Gold Dredging Company in Shasta County. It is estimated that there are 5,000,000 yards, having an average depth of 45 feet, and an average overburden of 10 feet. The dredge will dig to 60 feet. Both gold and scheelite are recovered.

Some difficulty was experienced in securing sufficient water from four wells drilled by the operators. This has been overcome through an arrangement for an ample supply from the Goler wells of the Yellow Aster Mining Company.

Tungsten Hill Mine. This mine, comprising 12 claims, is located in sec. 3, T. 28 S., R. 32 E., M. D., 1½ miles northwest of Havilah. Owners are T. M. Smith and E. E. Lambert of Havilah, California.

One hundred tons of ore from this property has recently been treated in the Basin View mill near Bodfish. Formerly some shipments were made to the mill at Weldon. Two men are working.

Bibl.: State Mineralogist's Report XXXVII, p. 579.

ORANGE COUNTY

Blue Light Mine (Silverado). This lead-zinc-silver mine comprises 13 claims consisting of 269 acres, 60 acres of which are patented, situated in Silverado Canyon, in the Cleveland National Forest Reserve, in secs. 11 and 14, T. 5 S., R. 7 W., S. B., 20 miles east of Orange; elevation 2650 to 3050 feet. The owner is Blue Light Silver Mines Company, C. S. Chapman, president, John J. Dwyer, vice president, Sam L. Collins, secretary-treasurer, and W. A. Young, manager, Fullerton, California.

The company has secured a development loan of $20,000 from the Reconstruction Finance Corporation for the purpose of shipping lead-zinc ore. The property produced from 1935 to 1941, during which period ores carrying high lead value were shipped, leaving a substantial tonnage of zinc ore that under present metal prices can be shipped at a profit.

Two parallel lodes known as the Blue Light lode and the Dike vein occur in the metamorphic rocks. The Blue Light vein has been the most productive and has been extensively developed along its outcrop for a considerable distance. This vein has a width of 2 feet to 6 feet. The ore is silver-bearing galena, associated with zincblende and pyrite. Seven known orebodies have been developed on the Blue Light lode. The Blue Light vein strikes N. 16° E. and dips 30° to 40° E. The vein, developed by seven tunnels, has an average width of 4 feet. At an elevation of 3000 feet, No. 2 tunnel has been driven south on the vein 350 feet. No. 3 tunnel, which is 50 feet in elevation below No. 2 tunnel, is a crosscut 200 feet to the vein, then drift south 470 feet on the vein. No. 4 tunnel level is located on south workings at an elevation of 2700 feet. A crosscut tunnel, driven east 700 feet at 400 feet from portal, cuts the vein. No. 5 tunnel at an elevation of 2764 feet was driven south on the vein for 1200 feet. There is a raise from No. 5 tunnel level in ore to No. 3 tunnel level. The orebody developed is 4 to 6 feet in width, and is reported to assay 0.25 ounces in gold, 25 to 50 ounces in silver, 3 percent lead, with 10 percent zinc. Orebody is developed 60 to 100 feet in length; average width 4 feet. No. 7 tunnel, which is in Pine Canyon at an elevation of 2460 feet, is driven 1200 feet south on Blue Light vein. The No. 7 tunnel level is 300 feet in elevation below No. 5 level. At 1200 feet from the portal, an incline raise is being driven to connect with crosscut from No. 5 tunnel level. The raise is now up 60 feet. Three short shoots of ore have been developed on No. 7 tunnel level. The ore extracted is reported to assay 0.06 ounces in gold, 12 to 20 ounces in silver, 4 percent in lead, and 13 percent in zinc.

Mine equipment consists of Clayton compressor, 14 by 8 by 8 inches, driven by Fairbanks-Morse gas engine; Sullivan portable compressor, capacity 300 cubic feet; Ingersoll-Rand portable compressor, capacity 110 cubic feet; jackhammers; stopers; and blacksmith shop.

Mill equipment consists of flotation plant, with a capacity of 50 tons. Mill is driven by 100-horsepower Fairbanks-Morse semidiesel gas engine. Six men are employed on development.

Bibl.: State Mineralogist's Reports XX, pp. 43-45; XXI, pp. 63-64.

Ortego Mine (Old Dominion). This lead-zinc property comprises 640 acres of patented land located in sec. 7, T. 6 S., R. 5 W., S. B., on the ridge west of Long Canyon, in the Cleveland National Forest Reserve, 6 miles west of Elsinore, a station on the Santa Fe Railroad; elevation 3000 feet. Owners are V. B. Anderson and Earl Frevert, 117 Spurgeon Street, Santa Ana, California. The property is operated under the name of Ortego Mining Company, Santa Ana, California.

The Old Dominion vein is in metamorphic rocks, near the contact of granite to the east. The formation in which the vein occurs is a crystalline rock that varies from a dark-brown felsite to a finely banded quartzose rock. The Old Dominion vein strikes N. 20° W.,

dips 45° E.; has a width of 6 to 8 feet, and an 18-inch streak of high-grade lead-zinc ore on the hanging wall. The vein material is heavily mineralized with pyrite and carries gold and silver, associated with galena and sphalerite. Analysis of the ore, made by Smith-Emery Company, shows 50 percent pyrite, 30 percent calcite, 13 percent limonite, 5 percent quartz and 2 percent siderite. The vein can be followed on the surface for a distance of 300 feet to the north where it has been displaced by a fault. Strike of fault is north, the dip 35° W.

Development consists of incline shaft sunk on the vein to a depth of 60 feet in Long Canyon. North of shaft 80 feet, a crosscut tunnel has been driven west 500 feet; at a point 40 feet west of the portal, it intersected the vein, then continued into the footwall of the vein for 460 feet. A drift driven north 100 feet intersects a winze from the upper tunnel level. At a point 200 feet north of incline shaft, a tunnel is driven northwest 50 feet to fault; drift south along fault 75 feet to shaft sunk on the vein to a depth of 45 feet, where the vein is cut off by a northward-trending fault. At this point a winze is sunk on the fault, which has a dip of 35° W., to a depth of 35 feet. There is a drift north 120 feet along fault 120 feet from crosscut tunnel. In the latter part of 1942, 100 tons was mined from incline shaft and shipped to United States Smelting, Refining & Mining Company, Midvale, Utah. Shipments assayed gold 0.02 ounces, silver 25.8 ounces, copper 0.3 percent, lead 3.5 percent, zinc 3.1 percent, iron 21 percent; total value per ton, $13.63. Sample of 15 tons of selected ore in ore bins was reported to assay gold 0.03 ounces, silver 45.2 ounces, lead 8.7 percent, zinc 9.11 percent.

Equipment consists of 12-horsepower gasoline hoist, one drill compressor, air drills, and blacksmith shop.

Mill equipment consists of two 6- by 8-inch jaw crushers; 3- by 3-foot ball mill; 4 home-made flotation cells. Capacity of mill is 10 tons per 24 hours. Three men employed sinking incline shaft to a depth of 100 feet.

Wilhunt Lead-Silver Mines (Morrow). These mines comprise 5 claims situated in Santiago Canyon, in sec. 27, T. 5 S., R. 6 W., S. B., 9 miles northeast of El Toro; elevation 2600 feet. The owner is L. W. Hunter, 3482 San Marino Street, Los Angeles. The claims were relocated by L. W. Hunter as Wilhunt group in 1942. The property was operated from 1896 to 1897 by the Santiago Mining Company, Orange, California. This company mined and shipped ore reported to carry 40 ounces in silver, 24 percent lead, and 10 percent zinc. The property was owned and operated by W. S. Morrow, Orange, California, from 1916 to 1935. From 1916 to 1925, W. S. Morrow made some small shipments of selected ore to U. S. Smelting, Refining & Mining Company's smelter, Midvale, Utah. In the latter part of 1942, L. W Hunter received a preliminary development loan from the Reconstruction Finance Corporation for $5000.

The vein strikes north, dips 35° E., and is 3 feet wide. It is in slates and quartzites along contact with diorite. The ore is galena and lead carbonate, associated with sphalerite and pyrite. Samples cut in upper tunnel and shipped to U. S. Smelting, Refining & Mining Company's smelter Midvale, Utah, assayed 0.02 ounces in gold, 35.8 ounces in silver, 23.6 percent lead and 10 percent zinc. Developed by three

tunnels. Upper tunnel is driven as crosscut 210 feet to vein, then drift south 100 feet on the vein. Ore shoot developed was 50 feet in length and stoped to surface. Winze on ore 30 feet below tunnel level. About 40 feet in elevation below upper tunnel, an intermediate tunnel has been driven N. 45° E. for 120 feet, then north on vein 20 feet. At 120 feet from the portal, a raise has been driven 30 feet but this raise does not connect with workings from upper tunnel level. At an elevation 130 feet below No. 2, or intermediate tunnel, a lower tunnel is driven N. 45° E. for 175 feet as crosscut to intersect vein developed in upper workings. Six men employed in retimbering workings in upper tunnel and also lower tunnel level.

When road to the property is completed, they plan to install compressor and flotation plant, with a capacity of 10 tons per 24 hours.

Bibl.: State Mineralogist's Reports XV, p. 516; XXI, p. 64.

RIVERSIDE COUNTY

Pawnee Mine (Carr Mine). This property comprises 4 claims in sec. 31, T. 8 S., R. 3 E., S. B., on the south slope of Beauty Mountains, 6 miles northeast of Oak Grove and 9 miles from Aguanga; elevation 4000 feet. Owners are Emerson L. Carr and William Carr, Aguanga, California. The mine is under lease to Riverside Tungsten Company, J. W. Harris, 711 Lasbrook Avenue, El Monte, California, and J. L. Richardson, 3900 Market Street, Riverside, California.

The present lessees have unwatered and cleaned out the underground workings on this property with money borrowed from the Reconstruction Finance Corporation.

Bibl.: State Mineralogist's Reports XXXVI, p. 48; XXXVII, pp. 583-584.

Phoenix Tungsten Property. This property, comprising 640 acres of patented land, is on the southeast slope of the San Jacinto Mountains, in Andreas and Murray canyons, in sec. 9, T. 4 S., R. 4 E., S. B., about 7 miles southwest of Palm Springs; elevation 1500 to 2800 feet. Owners are Andreas Canyon Club, Inc., of Palm Springs, California, who have leased to Jas. R. Maynard and Henry B. Tuttle, 135 Palo Verde Street, Palm Springs, California.

The scheelite has been found in the ridge between Andreas and Murray canyons. This ridge, which rises about 1000 feet above the bottom of each canyon, is extremely precipitous on the Andreas Canyon side. The country rock consists of granite, limestone, and some mica schist. The limestone occurs as thin, short remnants, largely altered to epidote and garnet. The strike is northeast, dip 45° SE. The sporadic outcrops of tactite in which the scheelite occurs may be 18 feet in width, and they are rarely longer. In a distance of about 900 feet along the ridge there are eight of these outcrops. Each contains at least two spots from 3 to 6 feet in width, which carry good tungsten values; but the length exposed on the surface in any of these is not sufficient to constitute a commercial ore shoot. The lessees propose to open several of these in the hope that they may be able to develop enough ore to support a small mill. They have built 3 miles of steep trail and are now taking in (by man-power) a 120-cubic-foot portable compressor.

Four men are working.

Fig. 1. Mill of Atolia Mining Company, Atolia, San Bernardino County. *Photograph by Walter W. Bradley.*

SAN BERNARDINO COUNTY

Atolia Mining Company. This company (1022 Crocker Building, San Francisco) has temporarily shut down the flotation section of its tungsten mill at Atolia while installing pumps to deliver an additional 20,000 tons from another tailings pile. The gravity section of this mill is running on ores from the Amity, Union, and Papoose mines, and from ten sets of leasers working at various places on the company's property. To keep this section of the mill up to its capacity of 250 to 300 tons per day, the table sands from the Union mill are being hauled to this plant.

Bibl.: State Mineralogist's Reports XV, pp. 830-839; XVII, pp. 370-372; XX, pp. 96-97; XXVII, pp. 365-366; Bull. 95, pp. 70-78 and 125-128.

Bagdad-Chase Mine (*Pacific Mines*). The property comprises 17 patented claims totaling 340 acres. It is situated in the Stedman mining district, in secs. 5 and 6, T. 6 N., R. 8 E., S. B., 7 miles south of Ludlow. Owner is John H. Hobbs, Glendora, California. The mine is under lease to Frank Royer, Red Mountain P. O., San Bernardino County, California, and Don L. Love, Ludlow, California.

The ore is deposited in an igneous breccia on a contact of monzonite and rhyolite. The brecciated material, which is the result of faulting, consists of both rhyolite and monzonite fragments cemented with highly siliceous material. Strike of the mineralized zone is east, and dips are 25° to 30° N. The average width ranges from 8 to 20 feet. The ore is very siliceous, being heavily stained with iron oxides and some copper oxides and silicates.

Development consists of three shafts, a vertical shaft 400 feet deep, another vertical shaft 125 feet deep, and an incline shaft 450 feet deep. Present operations are confined to shaft east of the main vertical shaft, from 90-foot level to surface glory hole. The present

operators developed ore in the footwall of the vein originally worked by former operators on the 60- and 90-foot levels. The orebody being stoped from these levels to the glory hole is 300 feet in length, 18 feet in width.

Since the early part of 1940, the shipments to American Smelting & Refining Company's smelter at Hayden, Arizona, have been 40,000 tons of siliceous gold ore, stated to carry gold $9.30 per ton, copper 0.80 percent, and silica 80 percent. At present, 100 tons of ore per week is being shipped.

Mine equipment consists of 25-horsepower gasoline hoist; one Ingersoll-Rand compressor, capacity 320 cubic feet; one Worthington portable compressor, capacity 320 cubic feet; air drills and 5-ton dump truck. Seven to 14 men are employed.

Bibl.: State Mineralogist's Reports XV, p. 790; XVII, pp. 341-342; XXVII, pp. 278-279; XXXVI, pp. 56-57; 232-233.

Black Jack Iron Mine. This mine comprises 10 claims known as Black Jack group, situated in the Bristol Mountains in sec. 24, T. 6 N., R. 12 E., S. B., 6 miles northeast of Amboy; elevation 2000 to 5000 feet. Owner is J. W. Gray of Siberia, California. The property is under option to Moharvey Minerals Corporation, Paul Hansen, president, William Duggan, secretary, and James O. H. Keyser, superintendent; offices, 257 South First Street, San Jose, California.

The iron deposit consists of five outcrops of magnetite occurring in dolomite near the contact of granitic rocks. The general strike is north, dip 50° E. These outcrops of magnetite occur in an area 200 feet in length by 100 feet in width, on the Black Jack No. 1 claim. Sufficient development work has not been done on the individual outcrops to make an estimate of tonnage. The outcrops of iron are 10 to 25 feet wide, 30 to 65 feet long, and are exposed for 20 feet above the dolomite. The ore is magnetite, assaying 57 percent iron, 2.7 percent silica, and 0.5 percent sulphur.

Equipment consists of Rix compressor, capacity 320 cubic feet; jackhammers; tractor; bulldozer and trucks.

Ten men are employed building camp at an elevation of 1900 feet and constructing a road from camp to the deposit at an elevation of 2500 feet. The company has applied to the Reconstruction Finance Corporation for a development loan.

Carbonate King Zinc Mine. This mine comprises 14 claims known as Crystal Cave group, situated on the western slope of Kokoweef Peak, in the Ivanpah Mountains, in the N½ sec. 4, T. 15 N., R. 14 E. and the S½ sec. 32, T. 16 N., R. 14 E., S. B., 5 miles southeast of Mountain Pass and 14 miles north of Cima, a station on the Union Pacific Railroad; elevation 5000 feet. Owner is L. P. Ressler, Mountain Pass, California. The property is under option to Crystal Cave Mining Company, H. C. Moore, president, Herman Wallace, secretary, 3352 Isabel Drive, Los Angeles.

The company is a Nevada corporation, with offices at Las Vegas, Nevada; under lease to W. F. Huston, Mountain Pass, via Nipton, California. Crystal Cave group was located by L. P. Ressler in 1928 but it was not until 1941 that zinc ore was discovered on the property by W. F. Huston, who had a contract to drive a crosscut tunnel to intersect the Kokoweef Cave for the Crystal Cave Mining Company.

The orebody occurs along a fracture or fractures in dolomitic limestone which strikes north, dips 60° W. and is 10 to 12 feet wide. The ore is sphalerite near surface which has been oxidized to form hydrozincite and smithsonite, associated with hematite and some cerussite (lead carbonate).

Development consists of single-compartment shaft sunk on an inclination of 70° to a depth of 120 feet, with levels at 50, 90 and 120 feet. On the 50-foot level, drift 55 feet north in ore; on 90-foot level drift 130 feet north in ore; on 120-foot level, crosscut west to orebody.

Ore mined and shipped to Ozark Mining & Smelting Company, Coffeeville, Kansas, to December 1942, was about 2000 tons, of 38 to 40 percent zinc with some lead, gold, and silver.

Analysis of Ore Shipments

Zinc	38.0%
Lead	1.1%
Iron	4.2%
Silver	10.3 oz.
Gold	trace
Insol.	12.0%
Lime (CaO)	12.0%
H_2O	5.2%

They are now hauling 10 tons per day to government stock pile at Jean, Nevada.

Mine equipment consists of 6-horsepower gasoline hoist; 130-cubic-foot compressor and jackhammers; aerial tramway 1100 feet in length from shaft to loading bins. Eight men are employed.

Colosseum Mine. This mine comprises 2 patented claims (Colosseum No. 1 and Colosseum No. 2), and 32 claims held by location, situated on the northwest slope of Clark Mountains, in sec. 19, T. 17 N., R. 13 and 14 E., S. B., 10 miles north of Valley Wells and 23 miles north of Windmill Station, on U. S. Highway 91; elevation 5500 to 6100 feet. Owner is the Colosseum Mining & Smelting Corporation, C. W. Gowman, president, Earl Thomas, secretary, 7371 West Sunset Boulevard, Hollywood, California. The property was under option to Harold Chase and Walter Lineberger, of Santa Barbara, California, from February 1938 to November 1942.

During this period, 5000 feet of diamond-drill work was done to determine the extent of orebodies; also development on lower tunnel level on No. 2 orebody. These parties suspended operations in the latter part of 1942, surrendering their option.

In the immediate vicinity of the Colosseum mine there is a great anticlinal fold of thick beds of stratified rocks, consisting of sandstone, limestone, dolomite, and thin-bedded shales. These rest upon gneissoid granite. Into this formation, there has been thrust a large, dome-shaped mass of quartz monzonite. Probably following the granite replacement, an intrusion of rhyolite porphyry occurred, in a general N. 30° E. direction. Subsequent to the intrusion of the rhyolite, intensive fracturing occurred in the rhyolite plug, with minor faulting. The major fracture strikes N. 20° W. to N. 20° E. A general mineralization of the rhyolite plug exists along intersecting fractures, metallic minerals being pyrite and chalcopyrite. The pyrite is auriferous. There are two types of ore deposits. The first, No. 1 orebody, is a mineralized network of intersecting fractures within the highly altered rhyolite plug. The

second, No. 2 orebody, is a contact deposit on contact of granite and rhyolite plug. The orebodies strike N. 60° E. and dip 80° SW. Estimated tonnage of ore developed in the two orebodies is reported to be 116,000 tons with an average value of $8 per ton in gold.

Since the Twenty-seventh Report of the State Mineralogist was issued (1931), the following development work has been done on the property:

At an elevation of 5700 feet, and 177 feet in elevation below upper tunnel, a lower tunnel has been driven N. 20° E. for 440 feet in granite, intersecting shaft at a depth of 200 feet; at 400 feet from the portal, it intersected a contact of granite and rhyolite porphyry. At 435 feet from the portal, a crosscut was run northwest 160 feet to west contact of No. 2 orebody, then drift along contact 160 feet in ore. The orebody developed along contact is 100 feet in length by 12 feet in width. Average value is reported to be $7.85 per ton. Upper tunnel is 800 feet in length; elevation 5877 feet. Upper tunnel level and intermediate tunnel level have developed No. 1 orebody which is 125 feet in length and 60 feet in width. Total amount of development is about 4000 feet.

Mine equipment consists of one 180-horsepower Fairbanks-Morse diesel engine; one 60 K.V.A. Fairbanks-Morse, 3-phase, 60-cycle, 460-volt generator; one 20-horsepower Westinghouse generator; one Ingersoll-Rand 2-stage (12- by 12-inch) (7½- by 12-inch) air compressor; one Sullivan drill sharpener; mine cars and air drills.

Mill equipment consists of concentration mill with a capacity of 50 tons per 24 hours; one 100-ton ore bin; one 3D Gates gyratory crusher; one Challendge ore feeder; one 24-foot bucket elevator; one 36- by 96-inch vibrating screen; one 5- by 4-foot Marcy type of ball mill; one 50-horsepower Westinghouse motor; one 18- by 48-inch trommel; one Cone classifier; 2 Wilfley tables; one 25-horsepower motor; 2 Groch flotation cells; one 12-foot rake classifier; one 16-foot conical settler; one 20-foot Dorr thickener; three 8-foot wood storage tanks; one 20- by 20- by 8-foot concrete water-storage tank, with a capacity of 35,000 gallons.

From well on Mojave tungsten claim, water is pumped through 5000 feet of 2-inch pipe line to water storage tank above mill. Previous to 1938, the mill was operated and produced 1000 tons of concentrates reported to have a value of $20 to $40 per ton in gold. Idle.

Bibl.: State Mineralogist's Reports XX, pp. 92-93; XXVII, pp. 291-292.

Dale Lake Sodium Sulphate Deposit. This deposit comprises nine 160-acre placer claims totaling 1440 acres, situated in secs. 26, 27, 34, and 35, T. 1 N., R. 12 E., S. B., 17 miles east of Twenty-nine Palms and 30 miles south of Amboy, a station on the Santa Fe Railroad; elevation 1180 feet. Owner is Chemical Mines Company, J. E. Bush, president, C. H. Hobson, secretary, 1204 West 31st Street, Los Angeles. The property was acquired under lease in March 1939 by the Desert Chemical Company, L. F. Foran, president, Lee Richardson, secretary and manager, 4031 Goodwin Avenue, Glendale, California.

The brines of the lake contain 22 percent sodium chloride and 7 percent sodium sulphate at a temperature of 70° F. Seven wells about 150 feet apart near the center of the lake have been drilled to depths of 150 feet. The brine from these wells is pumped to four 7-acre

crystallizing vats or spray ponds. The central pumping plant is located at the junction of the four crystallizing vats, with an intake from each vat. Spraying is under operation during the winter months for the recovery of mirabilite, glauber salt, hydrous sodium sulphate, $Na_2SO_4.10\,H_2O$. The sodium sulphate is separated from the solution by evaporation, or by chilling a saturated solution below 33° C. The concentrated solution from crystallizing vats is pumped by 15-horsepower electric-driven turbine pumps to two 5-acre finishing vats where sodium sulphate separates from the brine as glauber salt. The sodium chloride from the vats is pumped to one 80-acre vat from which it flows to four 5-acre vats for evaporation and recovery of NaCl. Sodium sulphate is harvested during dry summer months. Production started January 1940, and yearly production of sodium sulphate amounted to 15,000 tons. On the southwest end of the lake, there is a bedded deposit of thenardite (Na_2SO_4), anhydrous sodium sulphate, 600 feet in width and 4000 feet in length, average thickness 6 feet, with 6 to 8 feet of overburden. The overburden is stripped off and thenardite mined and hauled by truck to central washing plant where clay and sand are washed out. Thenardite is reported to carry 94 percent sodium sulphate. They are at present shipping 100 tons per day. The sodium sulphate is hauled by diesel trucks having a capacity of 30 tons each, to Amboy. Sodium chloride is shipped to Basic Magnesium Company, Las Vegas, Nevada.

The thenardite is dumped from trucks into 50-ton ore bin, then to roll-type crusher, where it is crushed to $\frac{1}{8}$-inch size and conveyed by 36-inch belt conveyor to two 100-ton circular wooden bins. From bins, it is loaded into box cars for shipment to pulp plants. Crystallized sodium sulphate also goes to circular bins for shipment.

Two fresh-water wells 400 feet in depth are located one mile west of the plant and water for plant and camp is pumped by Pomona turbine pumps, each driven by a 15-horsepower motor. Electric power plant consists of 300-horsepower 4-cylinder Fairbanks-Morse diesel engine, direct-connected, with 170 K. V. A. generator to furnish electric power for pumps and lights for camp. Twenty men are employed.

Desert Tungsten, Inc. W. De Witt of Randsburg, California, is president of the company, which has a lease from the Monarch Rand Mining Company on a portion of Baltic Gulch, about 2 miles southeast of Randsburg.

The overburden here will probably be from 6 to 12 feet thick. It will be stripped and the pay dirt moved by a carryall type of scraper. From a hopper, 2- to 3-yard capacity, by a belt conveyor to 2 sets of undershot riffles, each about 12 feet long, the undersize going to 4 riffled cylinders, tails to dewatering box. Capacity is about 50 tons per day. Gas engines supply power. Water comes from the Little Butte mine in Randsburg. Three men are working, setting up the plant.

Evening Star Mine (*Bernice Group*). This tin property, consisting of 4 claims, is on the north slope of the Ivanpah Mountains, about 9 miles north of Cima and 10 miles southeast of Valley Wells. Owners are Vaughn Maynard and Hiram Whisler, Santa Ana, California.

Property is under lease to C. F. Wendrick, Steel Service & Sales Company, Chicago, Illinois.

The country rock is a dolomitic crystalline limestone. There are granitic outcrops to the south of the deposit. The limestone is traversed by two intersecting fissure veins making an angle of about 40° with each other, the strike being N. 70° W. and S. 70° W. The northwest vein is practically vertical; the southwest vein dips to the northwest. These veins range from 2 to possibly 10 feet in width. The calcite, with subordinate tremolite gangue, carries cassiterite.

Development consists of a shaft sunk at the intersection of the two veins, vertical for about 35 feet and then inclined at 45° to the west for about 70 feet. The highly iron-stained vein is as much as 10 feet wide and is said to carry 2 percent tin. About 100 feet to the north, a shaft 30 feet deep has been put down on the vertical vein. The vein is about 4½ feet wide here. Crystals of cassiterite may be readily identified in this material. Some of the vein matter shows distinct fluorine stains and carries a little chalcopyrite. Trenching between the two shafts indicates that the vein is continuous.

A shipment of 25 tons to the Tin Processing Corporation, Texas City, Texas, in 1942, ran 6.27 percent tin. The operators are building a small mill some 10 miles north of the mine. It is about half a mile east of Valley Wells and about 200 yards south of Las Vegas highway. Four men are working.

Excelsior Talc Mine. This mine, comprising 13 claims, is on the southeast slope of the Kingston Mountains, 28 miles north of Valley Wells and about 30 miles southeast of Tecopa. The owner is Southern California Minerals Company, 320 South Mission Road, Los Angeles.

The talc bed occurs between a dolomitic hanging wall and a serpentine footwall. Strike is N. 45° W., dip 45° SE. Width is 15 to 50 feet, average being about 20. The talc is white and the lime content is low. It has been developed by tunnels. Upper tunnel has been driven northwest 800 feet. The lower tunnel, 165 feet on the dip below upper tunnel, has been driven northwest 1000 feet. At 450 feet from the portal, there is a winze 110 feet deep with levels at 50 feet and the bottom.

The owners have been shipping since 1936. Shipments aggregate about 10,000 tons. At present they are shipping 100 tons per month. The material is loaded at Dunn Siding about half way between Yermo and Kelso on the Union Pacific Railroad.

Equipment consists of 105-cubic-foot compressor and air tugger, at winze.

This company had to build 21 miles of road to make the property accessible. Three men are working.

Iron Horse Mine (formerly *Jack Rabbit*). This lead-silver property, comprising 2 claims, is in the Clark Mountain mining district, in sec. 29 (?), T. 16 N., R. 15 E., S. B., 18 miles north of Cima and 5 miles south of Wheaton Springs; elevation 5000 feet. Owner is Tony Marteletti, of Las Vegas, Nevada. The mine is under lease and bond to Malcolm L. Huckleberry, c/o Basic Magnesium Company, Las Vegas, Nevada, and Foster Dawson, 819 North Eleventh Street, Las Vegas, Nevada.

The country rock is limestone, into which has been intruded a granitic dike. The vein occurs in a fissure in the limestone a short distance from the dike. The strike is N. 20° W., dip 50° to 70° SW. It is traceable on the surface for about 700 feet. Its width ranges from a few inches to as much as 6 feet. Mineralization consists of lead carbonates with occasional spots of galena. These lead minerals carry some silver.

The property has been developed by an inclined shaft, on the vein, 190 feet, with levels at 60, 100, 150, and 190 feet. Only some 15 to 25 feet of drifting has been done on any of these except the 190-foot level where there is a drift north 45 feet, and on the 150-foot level, where there is a drift north 35 feet. Stoping has been done north of the shaft from the 190-foot level to about 25 feet above the 150-foot level for a length of about 30 feet. Five carloads of ore was shipped from these workings between 1927 and 1941. These cars averaged 2.7 ounces of silver, 16 percent lead, and about 2.0 percent zinc. The last car that came from the bottom of the shaft contained 23.0 percent lead, 2.20 ounces silver, and 2.4 percent zinc.

The present lessees have obtained a development loan from the Reconstruction Finance Corporation and expect to immediately (March 1943) begin sinking the shaft and extracting ore from existing levels.

Lavic Mountain Manganese Mine (*Garinger Mine*). It comprises 10 claims situated on the southeast slope of the Cady Mountains, in secs. 22 and 23, T. 8 N., R. 7 E., S. B., 7 miles northwest of Ludlow, 3½ miles north of Argos, a station on the Santa Fe Railroad; elevation 2900 feet. Owners are Lee W. Yim and A. N. Rabe of Ludlow, California. The property is under lease and option to Red Hill Gold Dredging Company, Walter Johnson, president, Charles L. Schifferle, secretary, and J. M. Elmer, manager, 311 California Street, San Francisco.

In 1917, the property was owned by I. D. Garinger, Daggett, California, and L. G. Root, Needles, California. In October 1917, 100 tons of selected ore was shipped to Lewellyn Iron Works, Torrance, California. Analysis showed manganese 35 percent, silica 12 percent, iron 0.5 percent.

Three manganese-ore outcrops occur on the claims on top of ridge in a belt some 200 feet in width and about 1500 feet in length. The main or west outcrop strikes east, dips 75° N., is 2 to 15 feet wide. The ore occurs against a hard red rhyolite agglomerate, along the southwest slope of the ridge. The ore is psilomelane and pyrolusite, with a gangue of silica, calcite, and unaltered fragments of rhyolite. Average sample of ore along outcrops is reported to carry manganese 32.6 percent, iron 1.2 percent, silica 18.0 percent. Total possible tonnage of ore carrying 25 percent grade is estimated to be 10,000 tons.

Development consists of a shaft 48 feet deep sunk along main outcrop; about 1500 feet east of shaft are two open cuts 6 to 8 feet deep and 20 feet in length. Width of ore is 4 to 6 feet; ore is reported to assay 30 percent manganese. Present work is confined to shaft; at depth of 48 feet, drift 20 feet in length in mixed ore. From surface cuts east and west of shaft, there is indicated ore shoot 30 feet in length and 6 feet wide, assaying 20 percent manganese.

Present operators are making screen tests on ore extracted during development work to determine if product containing 35 percent manganese can be produced. Ore screened through ⅜-inch screen indicates 70 to 80 percent ore, assaying 30 percent manganese. Oversize is discarded as waste. Three men are employed.

Bibl.: Bull. 76, p. 62; State Mineralogist's Reports XVII, pp. 355-356; XXVII, pp. 337-338.

Mine Development Company. This company, Hewitt S. West, president, Pasadena, California, James I. Moore, manager, San Bernardino, California, has had a lease on the Pride of Mojave mill, 4 miles south of Mojave, and on 12 mining claims owned by George A. Barrington, in the so-called South Field of El Mirage Lake district, about 10 miles northwest of Adelanto.

During the tenure of its leases, both of which have now been relinquished (March 1943), the company shipped and treated between 600 and 700 tons of tungsten ore which is reported to have averaged ½ percent WO_3.

Ord Mountain Mine. This mine, comprising 22 claims, 17 of which are patented, is situated in the Ord Mountains, 14 miles southeast of Daggett; elevation 4000 to 5500 feet. Owner is Frank A. Werner, 2029 West Washington Street, Los Angeles. Property is under option to Symons Brothers Screen Company, 100 North Orange Drive, Hollywood, California.

The present lessee has confined his operations to the Rio Vista workings. Former developments here consisted of the lower crosscut tunnel driven east 770 feet, with a drift south 437 feet and north 100 feet, at 700 feet from the portal. The upper tunnel, approximately 125 feet above, was driven as a crosscut east 250 feet, with drifts north and south. A sublevel, intermediate, and upper level were developed through a 175-foot raise from this tunnel. The sublevel is 50 feet above crosscut, intermediate is 40 feet above sublevel, and upper level is 80 feet above the intermediate. The present operator has put up a raise 80 feet above sublevel from which he shipped 4 cars of ore. Four other cars have been shipped from various places in these workings. The company is now cleaning out the upper level and expects to raise to surface from its north end. This is a part of a development program which it is hoped will develop sufficient ore to warrant the erection of a mill.

Equipment at mine consists of 105-cubic-foot compressor, blacksmith shop and 75-ton bin. A camp to accommodate some 25 men has been provided. They are working from 12 to 15 men.

Bibl.: State Mineralogist's Reports X, p. 528; XII, p. 234; XIII, p. 326; XV, p. 789; XVII, pp. 276-278; Bull. 50, p. 336.

Placers, Inc. W. T. Thurman and associates, of Lodi, California, have leases and options from various owners on some 150 acres about one mile north of the Union mine at Atolia.

This property appears to be typical of the placer ground in this area. There is some 12 to 14 feet of overburden, with from 3 to 6 feet or more pay dirt.

The material is loaded into a 6-yard hopper by a 2½-yard dragline shovel; from hopper to 5½- by 20-foot drier trommel (oil fired), trommel openings 1 inch; oversize to tailings stacker; screenings by drag

conveyor to hopper to belt conveyor to centrepact mill. This equipment is one unit mounted on one frame, which, in turn, is mounted on caterpillars. From centrepact mill to conveyor to the dry concentrator unit, hopper to 38-inch by 20-foot trommel, ¼-inch openings; oversize by conveyor to tailings stacker; screenings to V-shaped bin under the trommel from which it is fed to a battery of Mexican-type dry washers on each side of the bin; tails to conveyor to stacker. This unit is also mounted on caterpillars. Both units are of all-steel construction. Capacity expected to be 100 yards per hour. The concentrates are then sluiced over 15 feet of riffles to a 30-inch Straub ball mill to a pan amalgamator to a Straub table, to drier and electric separator in a centrally located stationary plant. All machines are motor-driven. Power is supplied by Southern Sierras Power Company.

Nine men are employed. They expected to be in operation by the middle of February 1943.

Spud Patch Placer. Hoefling Brothers, P. O. Box 786, Sacramento, California, have a lease on about 200 acres, comprising the entire Spud Patch, about a mile southeast of Atolia. Allen E. Jones is in charge of operations.

This ground was intensively worked during World War I, when many tons of scheelite were produced by hand work. The material recovered from the sand and gravel of this area was almost pure scheelite in rounded pieces from the size of a walnut or smaller to those weighing almost a hundred pounds. In this area, which is something over a mile long and more than a quarter of a mile wide, there is from 8 to 40 feet of overburden under which is the pay streak averaging about 3½ feet in thickness. There is no real bedrock, the material underneath being similar to the overburden. Boulders weighing 200 pounds or more are very scarce. The pay streak is sand and fine gravel, 80 percent of which will go through a 10-mesh screen, and there is less than 10 percent slime. As in practically all placer deposits, there are, in places, concentrations of values greater than the average. These are believed to occur along the courses of old stream beds.

The ground is stripped and mined by a bulldozer which delivers the material to one 2-yard and one 1½-yard dragline shovel by which it is loaded into trucks and hauled 4 miles northeast to the washing plant on the slope west of Cuddeback Dry Lake. Here it is dumped either into a 30-ton hopper or on a stock pile. From the stock pile, a tractor with blade delivers it to hopper as needed. From the hopper by pan feeder to 6- by 25-foot trommel with a 10-foot scrubbing section, ⅝-inch, with 10-mesh jacket screen; minus 10 pumped to two 2-cell Pan American jigs, the hutch from which goes through Triton continuous amalgamators and then over a Straub table. The minus ⅝-inch plus 10-mesh goes to a 2-cell Bendelari jig, hutch back to 10-mesh circuit; plus ⅝-inch minus 1-inch goes to a 2-cell Bendelari jig. The plus 1-inch from trommel goes to tailings stacker belt over a section of which is built a "dark room" in which a large ultraviolet-ray light is mounted over the belt. Two men pick spuds from the belt. This plant is a converted boat which formed part of a dragline dredge.

Water is obtained from 3 wells, half a mile, one mile, and 1½ miles distant. Deep well pumps deliver the water to a reservoir 125 feet in diameter in which about 8 feet of water is stored. The plant has a

capacity of 70 yards per hour and is operated at capacity 10 hours each day. Electric power is supplied by Southern Sierras Power Company. Fifteen men are now working. A full crew would consist of 20 men.

Bibl.: State Mineralogist's Reports XV, pp. 830-839; Bull. 95, pp. 144-145.

Stewart Manganese Mine. This mine comprises 12 claims situated in the Whipple Mountains, in sec. 6, T. 3 N., R. 25 E., S. B., 42 miles by road southeast of Needles, 6 miles southeast of West Well and 14 miles by road to Needles-Blythe road; elevation 1500 feet. There is a 72-mile truck haul to stock pile at Parker, Arizona. Owner of the property is J. W. Stewart, of Needles, Arizona. It is under lease to Mineral Materials Company, A. S. Vinnell, president; Claire W. Dunton, manager; and C. H. Pierce, superintendent, 1182 Masselin Avenue, Los Angeles.

A series of parallel veins occurs in andesite and andesitic breccia; strike northwest. Dips vary from 60° to 70° SW. Widths vary from 12 inches to 3 feet. Four veins have been exposed on the property by open cuts, shallow shafts and short tunnels. The ore mined is psilomelane, associated with pyrolusite. Average grade of ore shipped is 30 percent manganese.

The principal development work is confined to No. 1 vein which occurs along a fault fracture in andesite. The mineralized zone is 25 feet wide and 75 feet in length, with a 3-foot vein of manganese on the footwall. Vein strikes N. 30° W., dips 70° W. There is an open cut on the vein 70 feet in length and 12 feet in width. Twenty feet below the open cut, a tunnel is driven southeast 60 feet. Ore from open cut and tunnel goes to 50-ton ore bin. These workings have produced 150 tons of ore reported to carry 31 percent manganese.

No. 2 vein has been developed by a short tunnel 20 feet in length. On No. 3 vein a shaft has been sunk to a depth of 14 feet, with a drift 20 feet in length on the vein. The vein material is mixed with fragments of andesite. Screen tests of this material produced 30 percent manganese in the fines. No. 4 vein has been exposed on the surface by open cut 200 feet in length. Width of ore exposed is 12 inches to 2 feet.

Equipment consists of 3 portable compressors, one with a capacity of 365 cubic feet, the others have a capacity of 110 cubic feet; tractor and trucks.

At present, they are hauling ore to Metals Reserve Company's stock pile at Parker, Arizona. Ten men are employed.

Vulcan Iron Mine. This mine, comprising 7 claims, is in sec. 25, T. 10 N., R. 13 E., S. B., on the north slope of the Providence Mountains, 9 miles south of Kelso, a station on the Union Pacific Railroad. The property has been purchased from C. Colcock Jones by Kaiser Company, Inc., Henry J. Kaiser, president; offices, Latham Square Building, Oakland, California; local office, Fontana, California; Robert E. Tally, superintendent; George Havas, chief engineer.

This iron deposit is in dolomitic limestone at its contact with quartz monzonite. The deposit strikes east. The contact, forming the western limit, dips 70° W. The monzonite occurs at the west end. The limestone envelopes the other three sides. The deposit is approximately 300 feet wide by 1000 feet long and is estimated to contain 2,500,000 tons of ore averaging about 51 percent iron.

FIG. 2. Vulcan iron mine, Kaiser Company, Inc., showing open cut and two upper benches. Nine miles south of Kelso.

The deposit is being developed by an open cut and two benches. The open cut, which is at the base of the mountain, is some 400 feet long by 300 feet wide by 60 feet deep. The west end of this cut is at the contact. The east end of the cut rises about 60 feet to the floor of the lower bench which is approximately 50 feet wide by 300 feet long. The face of this bench is some 40 feet high. The upper bench, 60 feet above, is 40 feet wide by 150 feet long. The length is now being extended to the north. From this bench, the east end of the deposit will be mined from this level to the top, a vertical distance of 127 feet.

The benches are drilled with 2½-inch Sullivan rotary and 9-inch churn-drill holes to 10 feet below the bottom. The holes are blasted with 60 percent dynamite. The average shot breaks 30,000 tons. Ore is loaded into 22- and 33-ton trucks by two 2½-yard power shovels. It is hauled to a hopper at the level of the lower bench, then fed to 42- by 48-inch jaw crusher, where it is crushed to minus 8 inches; it then falls onto a stock pile. An inclined 40-inch conveyor, in a tunnel under the stock pile is fed by an apron feeder and empties directly into trucks. These trucks haul 9 miles over an oiled road to a stock pile on a siding at Kelso; from stock pile through apron feeder to 40-inch belt equipped with automatic weighing device, direct to railroad cars. They are shipping 2400 tons daily to the Iron & Steel Plant of Kaiser Company, Inc., Fontana, California.

Power is supplied by 280-horsepower Fairbanks-Morse diesel engine, direct-connected to 186-kw generator. A modern camp to house 65 men has been built. One hundred men are employed, 35 families living in trailers at Kelso.

Bibl.: State Mineralogist's Reports XV, pp. 820-821; XXVI, p. 264; Bull. A. I. M. E., Sept. 1915, p. 1889; A. & M. J., April 17, 1909.

Iron & Steel Plant of Kaiser Company, Inc. This plant is located at Fontana, California. Henry J. Kaiser is president, Thomas Price, manager, and George R. Ramsay, assistant manager. Plant capacity is 2500 tons of iron ore per 24 hours. Plant was blown in December 1, 1942. It is located on 1400 acres near Fontana, San Bernardino County. The plant consists of 90 coke ovens and blast furnace about 25 feet in diameter by 100 feet in height. Blast furnace treats iron and limestone at a temperature of 2700°. From blast furnace, pig iron will go to 5 open-hearth furnaces where iron will be mixed with scrap metal, then heated to 3500°, and made into steel. Open-hearth building is 500 by 700 feet. Steel billets from open-hearth furnaces go to rolling mill. The rolling-mill building is 1100 feet in length by 300 feet in width. There is also a by-products plant for coal-tar products and benzoil. The coal for coke ovens is shipped to the plant from Utah. Limestone is furnished by California Cement Company, Colton, California. Six thousand men are employed.

Vulcan Mine (McClintock). This gold-copper property comprises 5 claims situated on the northwest slope of Ship Mountains, in Sec. 11, T. 5 N., R. 15 E., S. B., 2½ miles southeast of Siam, a station on the Santa Fe Railroad; elevation 1600 feet. Owner is Helen C. King, 1030 South Magnolia Street, Los Angeles. The mine is under lease to Vulcan Mining Company, Leon O. Compton and H. I. Schuyler, Cadiz, California.

Located in 1898 by McClintock, the property has been worked off and on to date. From 1935 to 1937, it was under lease to Funk Brothers and H. J. Jackson, Ludlow, California. During this period the production was $50,000 in gold, the ore being mined from the 100-foot level to surface. Ore shipped is reported to have averaged $40 per ton in gold. From February 1941 to February 1942, the property was under lease to Rashly, Inc., William W. Dowsing, president, R. C. Aurand, secretary, Santa Monica, California. They shipped 1500 tons of ore to American Smelting & Refining Company's smelter, Hayden, Arizona. Shipments carried the following values: gold 0.345 ounces, silver 0.12 ounces, copper 0.21 percent, silica 70 percent, alumina 10 percent, iron 5.1 percent; total value $11.54 per ton.

The gold vein occurs in quartz diorite; strike N. 10° E., dip 80° E.; width 8 to 12 feet. In the hanging wall of the gold vein and parallel to it, is a copper vein which occurs on the contact of quartz diorite and limestone. Limestone is the hanging wall, quartz diorite the footwall. The copper vein has the same general strike as the gold vein and is from 6 to 12 feet in width. The copper vein carries from 2 to 3 percent copper and $6 in gold.

Development consists of two vertical shafts. South shaft is 175 feet deep, and 150 feet north of this shaft, the north shaft has been sunk to a depth of 500 feet. The present mining and development work is being done from the south shaft. On the 50-foot level, drift 150 feet north to north shaft and 125 feet south; on the 100-foot level, drift 285 feet south, of which 100 feet was on the vein and 125 feet north on 150-foot level, drift north 150 feet to north shaft; on 175-foot level drift north 25 feet. From 100-foot level to surface, the gold vein has been stoped both north and south of shaft. Copper vein is stoped from the 150-foot level to 50-foot level.

Mine equipment consists of 12-horsepower Thomas hoist, (12 by 12 inches); Ingersoll-Rand compressor; air drills; cars; and 3-ton truck. Six men are employed.

White Moon Magnesite Mine. This mine comprises White Moon placer claim, in the NW¼ sec. 22, White Moon No. 2 placer claim in the NE¼ sec. 22, White Moon No. 3 placer claim in the SW¼ sec. 15, White Moon No. 4 placer claim in the SE¼ sec. 15, T. 8 N., R. 21 E., S. B., total 640 acres, in the Sacramento Mountains, in Sunrise mining district, 11 miles southwest of Needles; elevation 2000 feet. Owners are B. E. Hubbard and William W. White and associates, 6263 Vesper Street, Van Nuys, California; under option to J. Lex Brown, 1850 Waterman Avenue, San Bernardino, California. The property is subleased to American Magnesite Company of America, Irving Bromberg, president; A. Bromberg, secretary; M. I. Lieberson, manager; H. A. Pelton, engineer, 1349 Washington Boulevard, Los Angeles; J. Lex Brown, superintendent.

A stratum of magnesite occurs along anticlinal fold in dolomite, and overlies a thick series of volcanic rocks, andesite and andesitic breccia. The general strike is northwest, dips vary. The general dip of the stratum is 15° NE. The sedimentary bed of magnesite is intensely folded and tilted. Sufficient development work has not been done on the bed to determine its thickness, which is probably 8 to 10 feet. The dolomite beds overlie the bed of magnesite, having a thickness of 8 to 10 feet. The exposure of magnesite can be traced on the surface for a distance of 750 to 1000 feet.

Development consists of a number of shallow trenches, short tunnels and open cuts made at intervals along the bed of magnesite. Estimated tonnage of probable ore developed is stated to be 40,000 tons of commercial grade.

They are building a road from Needles to the deposit 11½ miles in length. The company has acquired the Chula Vista calcining plant, formerly operated by the Tycrete Chemical Corporation, Chula Vista, San Diego County. The plant has a capacity of 100 tons per day. They plan to ship the magnesite from deposit to Chula Vista for treatment. Six men are employed on construction of road and development work on an open cut on the southeast end of deposit.

SACRAMENTO FIELD DISTRICT

CURRENT NOTES ON ACTIVITY IN THE STRATEGIC MINERALS, SACRAMENTO FIELD DISTRICT

By Charles V. Averill*

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AMADOR COUNTY

Copper

Newton Mine. This mine is four miles east of Ione on the highway to Jackson. It was opened in the early sixties and was equipped with an 80-ton smelter in 1889. Until the mine was reopened recently, the last production had been in 1900. Workings reached a depth of 430 feet. The mine is now being operated by J. H. Lester, who obtained a preliminary development loan from Reconstruction Finance Corporation. The first carload of ore was shipped in April 1943. Diamond drilling by the U. S. Bureau of Mines is said to have proved that ore exists at greater depth than mine workings have reached.

CALAVERAS COUNTY

Quartz Crystals

Rough Diamond Mining Co. This company is reopening the Green Mountain or McSorley quartz-crystal mine in secs. 18, 19, T. 5 N., R. 12 E. and sec. 24, T. 5 N., R. 11 E., M. D., two miles south of Mokelumne Hill, with funds derived from a preliminary development loan granted by Reconstruction Finance Corporation. Crystals are found in a buried river channel, and between 1897 and the close of the war of 1914-18 shipments of 22 tons were made. Such material is in great demand for war purposes, as wafers of the quartz about an inch square are used to control the frequency of all radio transmitters including those installed in airplanes and military tanks. Such quartz must contain no flaws.

* District Mining Engineer, Sacramento Field District, Division of Mines. Manuscript submitted for publication May 6, 1943.

FIG. 1. Chaix chrome mine operated by C. D. Jones.

EL DORADO COUNTY

Chromite

Chaix Mine. During the war of 1914-18, this mine produced at least five carloads of chrome ore. It is in sec. 14, T. 8 N., R. 9 E. M. D., two miles east of Latrobe. The mine is now (May 1943) being reopened by C. D. Jones of Rescue with funds derived from a preliminary development loan granted by Reconstruction Finance Corporation. Shipments of chrome ore are expected to start soon.

Joerger Mine. This property in sec. 35, T. 10 N., R. 8 E., M. D. is two miles by dirt road from a point on the Sacramento-Placerville highway near Clarksville. It probably produced several carloads of chrome ore during the war of 1914-18. Chas. C. Holden of Rescue is leasing it from J. E. Joerger, Clarksville. Holden is now (May 1943) starting to reopen it with funds derived from a preliminary development loan granted by Reconstruction Finance Corporation.

Copper

Dodson Mine. This property has been known also as the Rip and Tear copper mine. It is in sec. 3, T. 8 N., R. 9 E., M. D., two miles north of Latrobe. It is leased by W. J. Varozza of Latrobe, via Shingle, from R. L. Dodson of the same address. A little copper ore of good grade was shipped in 1917, and the mine is believed to contain more such ore. Varozza expects to reopen it soon with funds derived from a preliminary development loan granted by Reconstruction Finance Corporation.

Volo Mining Company. This company recently operated a mill for the production of chrome concentrates in sec. 22, T. 10 N., R. 10 E. M. D., three miles southeast of Placerville. The mill has been remodeled to make copper concentrate by flotation. F. V. Phillips, Box 586 Placerville, is in charge. He is reopening the Lillyama mine in sec. 3 T. 11 N., R. 9 E., M. D., 15 miles northwest of Placerville.

NEVADA COUNTY

Chromite

Parker Chrome Mine. This mine is in sec. 17, T. 13 N., R. 8 E., M. D., half a mile east of the Auburn-Grass Valley highway at a point 6½ miles north of Auburn. It is leased from Herman Oest by Chester C. Butler, Grass Valley, and John C. Wold, Auburn, who are reopening the mine with funds derived from a loan granted by Reconstruction Finance Corporation. Chrome ore was produced during the war of 1914-18.

Manganese

Stearns and Owens. This is the name of new operators, whose address is Box 661, Auburn, of the manganese mine formerly operated by Mangachrome Company, a partnership of Neville and Slater. The mine is in sec. 17, T. 14 N., R. 8 E., M. D., at the junction of the Lime Kiln and Wolf roads. The former operators delivered roughly 500 tons of manganese ore to Metals Reserve stockpile at Auburn. Mining is by open-pit methods.

The pit is now 450 feet long, 50 feet wide, and 25 feet deep in four benches. A cross-section at the south end shows that it is mostly in slate striking N. 15° W., and dipping 76° E. Some interbedded volcanic material, probably basalt of very fine grain, is seen in beds from a few feet wide to 10 feet wide; there are also a few beds of chert 2 feet wide. Black oxides of manganese occur in occasional lenses, which contain some rhodonite. This is discarded in hand-sorting.

Present operators are continuing operations in the pit with a diesel 75 Caterpillar tractor and 12-cu. yd. Bucyrus Erie carryall. They also have an 8-cu. yd. carryall not in use, portable air compressor, and other power-tools and trucks.

REDDING FIELD DISTRICT

CLERBUS-MAE TUNGSTEN PROSPECT, TRINITY COUNTY

By J. C. O'Brien*

The Clerbus-Mae tungsten prospect consists of two unpatented quartz claims located in sec. 31, T. 9 N., R. 8 E., H., in the New River mining district of Trinity County, about 30 miles north of Denny by mountain trail, and about half a mile west of Eagle Creek, at an elevation of 4000 feet. Owners are Burtt L. Berry, 1451 Larkin Street, San Francisco, and Jim Robie, Fairfax, California.

This property was formerly operated as a gold mine by Andrew Jacobsen and partners, who treated the ore in a small elliptic mill, impact amalgamator, and a small Wilfley-type concentrating table run by a 4-horsepower single-cylinder gas engine. The quartz is said to have averaged $13.00 a ton, but recovery was poor.

The mine is developed by an adit driven S. 10° W. through diorite. The diorite shows jointing that strikes S. 50° E., and dips 77° NE. About 80 feet from the portal, a 2-inch quartz vein dipping 60° N. was followed S. 80° E. for about 40 feet. Both walls of the vein are diorite. Scheelite fluorescence was prominent in the vein about 30 feet from the adit, where small vugs and iron stains seem to be more prominent. The fluorescence is strongest at the hanging-wall contact with the diorite, which has been altered for a depth of a quarter of an inch. The feldspar and many of the dark minerals seem to have been removed and replaced in part by quartz. It may be that the tungstic acid solution acquired its calcium to form scheelite from the feldspar in the diorite. No calcite was observed in the vicinity of the vein and no cross-fractures or seams were observed where the fluorescence was strongest. The vein quartz has a slight ribbon structure, indicating successive periods of deposition.

A parallel quartz vein about half an inch wide occurs in the footwall, and a few fluorescent grains were seen in spots near its east and west faces. The vein was followed about 40 feet west of the adit, but no fluorescence was noted.

These veins outcrop on the hill above the adit, where they are from 4 to 6 inches wide. No scheelite was seen on the outcrop. The scheelite-bearing vein is too narrow and apparently too low-grade for commercial development.

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* District Mining Engineer, Division of Mines. Manuscript submitted for publication April 20, 1943.

GEOLOGIC BRANCH

CURRENT NOTES

By Olaf P. Jenkins*

In This Issue

Four contributions on geology and mineral deposits are published in this issue: (1) a description of a new rock, by Raymond M. Alf, *Mylonites in the Eastern San Gabriel Mountains;* (2) a geologic map of metamorphic and granitic rocks in an area in the southern Sierra Nevada, with a description of them, by Cordell Durrell, *Geology of the Sierra Nevada Northeast of Visalia, Tulare County, California;* (3) a description of tungsten deposits found in this area, by William O. Jenkins, *Tungsten Deposits Northeast of Visalia, California;* and (4) a geologic map prepared in great detail of an area in the Coast Ranges, by Ivan F. Wilson, *Geology of the San Benito Quadrangle, California.* This geologic map is published in colors and covers a topographic quadrangle of the U. S. Geological Survey. It represents the first of a series of such maps which the Division of Mines expects to issue.

Recent Publication

BULLETIN 118, *Geologic Formations and Economic Development of the Oil and Gas Fields of California,* compiled under the direction of Olaf P. Jenkins, is now released under one cover. It consists of four parts, as follows:

Part One—Development of the Industry, pp. 1-80.

Part Two—Geology of California and the Occurrence of Oil and Gas, pp. 81-276.

Part Three—Descriptions of Individual Oil and Gas Fields, pp. 277-664; including tabulated data on wells drilled outside of the principal oil and gas fields; also citations to selected references, throughout Part Three.

Part Four—Glossaries, Bibliography, and Index, pp. 665-773; includes glossary of the geologic units of California, bibliography, and index to the entire volume.

Bulletin 118 contains 6 plates, 283 figures, 81 index maps to individual oil and gas fields (on the same scale as the Geologic Map of California—1:500,000), and an Outline Geologic Map of California Showing Oil and Gas Fields and Drilled Areas—Economic Mineral Map of California No. 2, Oil and Gas, scale 1:1,000,000 (folded in pocket).

* Chief Geologist, Geologic Branch, Division of Mines.

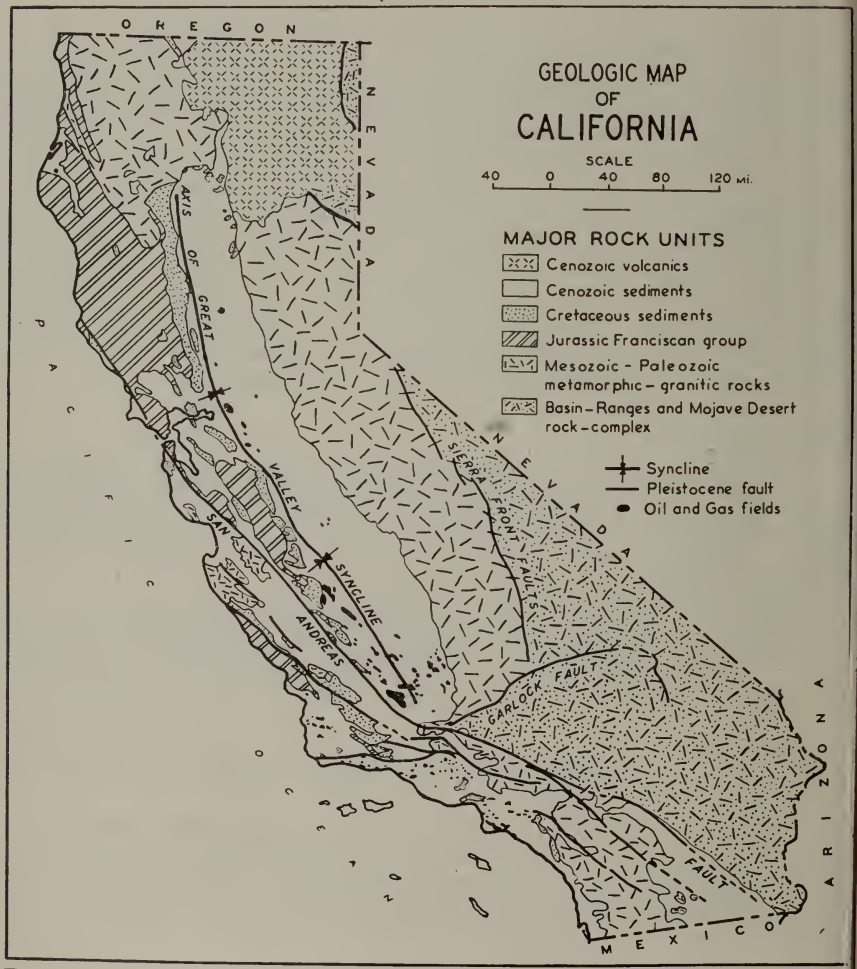

FIG. 1. Generalized geologic map of California showing major rock units, majo structural lines, and oil and gas fields. *Prepared by Olaf P. Jenkins.*

MYLONITES IN THE EASTERN SAN GABRIEL MOUNTAINS

By Raymond M. Alf *

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ABSTRACT

The author has discovered thick zones of the dense crush-rock, mylonite, in the Cucamonga district 40 miles east of Los Angeles, an area already well known to geologists because of large and complicated alluvial fans and notable Pleistocene and Recent faulting.

Mylonites are fine-grained rocks which may look like smeared porphyries or even banded chert. They are composed of fragments most of which are very small, but unlike gouge they are firm and solid rocks, probably because they were formed at depths and under pressures where cavities could not persist.

The mylonite zones of the Cucamonga district are roughly paralleled by the Pleistocene faults. Both occur along the mountain front and curve up canyons. However, the mylonites formed much earlier than the Pleistocene, probably during the late Mesozoic, for they seem to grade into schists and gneisses, they are intruded by granitic rocks, and they furnished abundant debris to nearby Tertiary sediments. Most notable is the preservation here, perhaps as well as anywhere in North America, of what appear to be the actual stages in the formation of dynamically metamorphosed rocks.

INTRODUCTION

During the summer of 1942, when the writer was engaged in the petrographic study of the southeastern San Gabriel Mountains, he discovered large masses of mylonites in the vicinity of San Antonio Canyon. The study of these rocks is being continued, and the writer hopes to make a more complete report on them at a later time.

The terminology of Waters and Campbell [1] has been found satisfactory and is used here. These authors give a genetic definition for mylonite that has four qualifications:

> "First, a mylonite is a microbreccia produced by the milling down of the original rock material into an aphanitic paste which can only be resolved by the microscope; second, the rock must possess a flow structure, or lamination, as a result of the streaking out of the pulverized paste; third, the pulverization must have occurred under such conditions that the rock retains its coherence; and fourth, the rock must be characterized by cataclastic rather than crystalloblastic textures."

* Webb School of California, Claremont, California. Manuscript submitted for publication February 11, 1943.

Gratitude is here expressed to Dr. A. O. Woodford for the use of the Pomona College geology laboratories and library and particularly for his help and encouragement in the preparation of this report. Also the writer wishes to acknowledge the cooperation of the Forest Service of the United States Department of Agriculture.

[1] Waters, A. C., and Campbell, C. D., Mylonites from the San Andreas fault zone: Am. Jour. Sci., vol. 29, pp. 474-475, 1935.

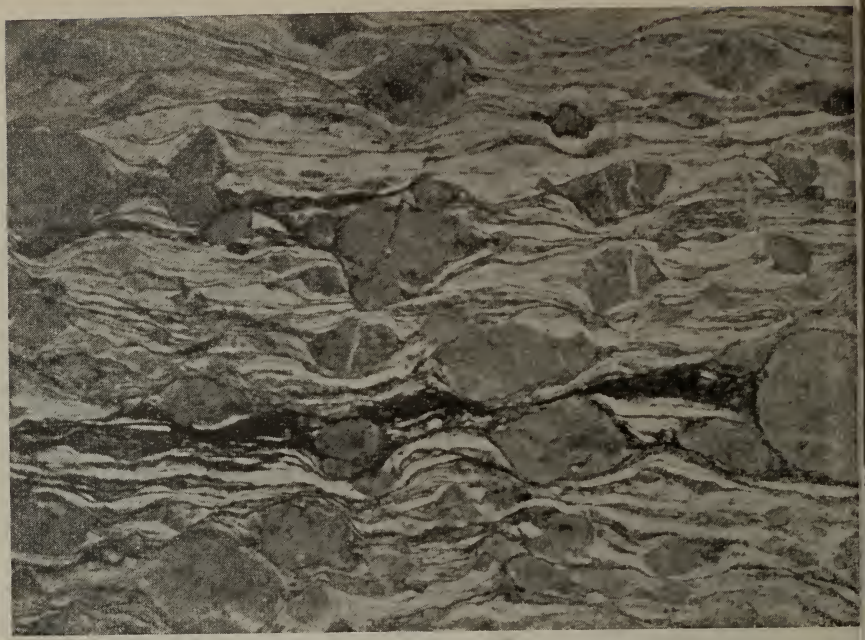

FIG. 1. Photomicrograph of mylonite derived from a granitic rock (ordinary light x16). The gray areas are orthoclase, and the light areas are mostly quartz Evey Canyon.

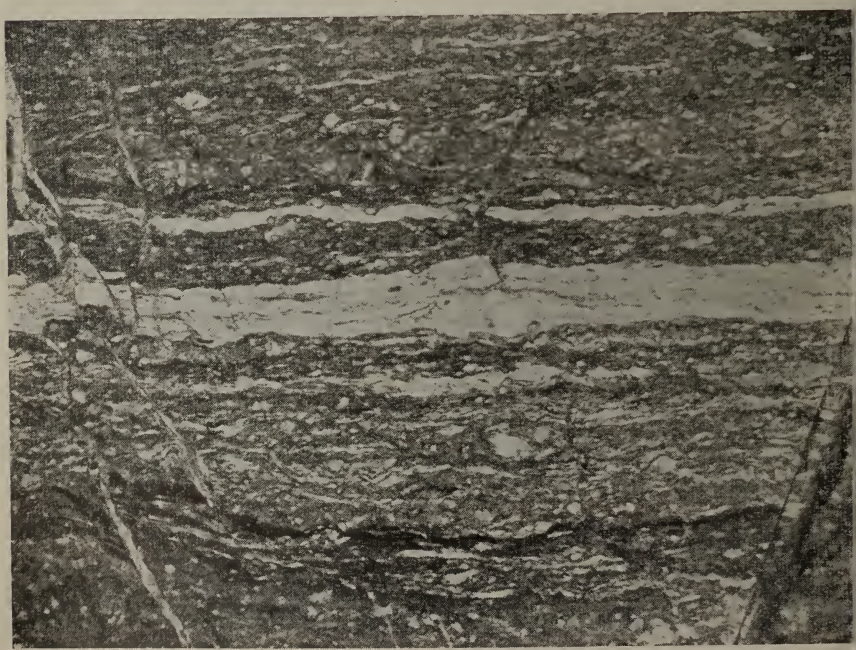

FIG. 2. Photomicrograph of mylonite from Evey Canyon (ordinary light, x16). This was originally a granitic rock.

FIG. 3. Photomicrograph of limestone mylonite from Evey Canyon (ordinary light, x16). The large grains are mostly diopside and are probably porphyroclasts.

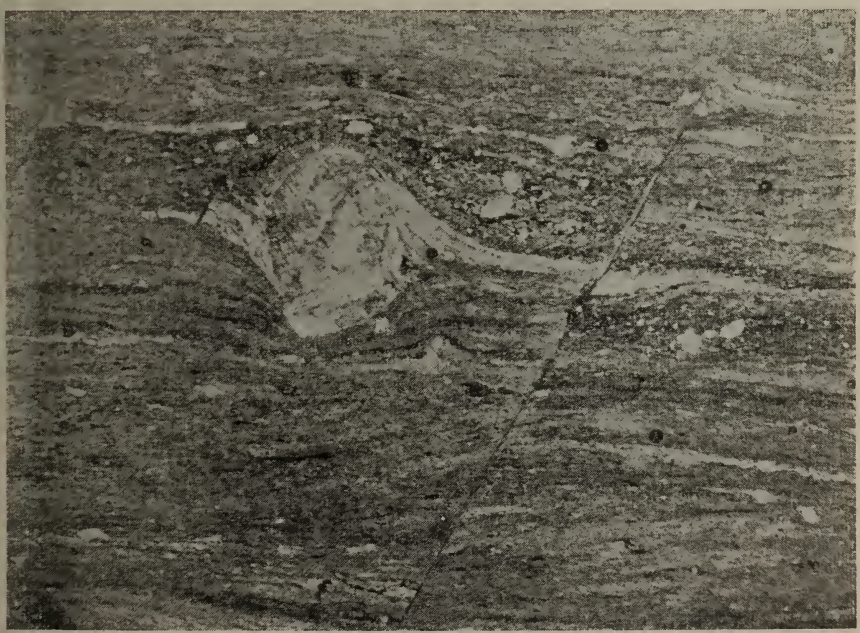

FIG. 4. Photomicrograph of mylonite derived from a dark-gray granitic rock (ordinary light, x16). The porphyroclast is feldspar; it has an irregular nucleus of clear orthoclase (or microcline) and a periphery of albite. Cucamonga Canyon.

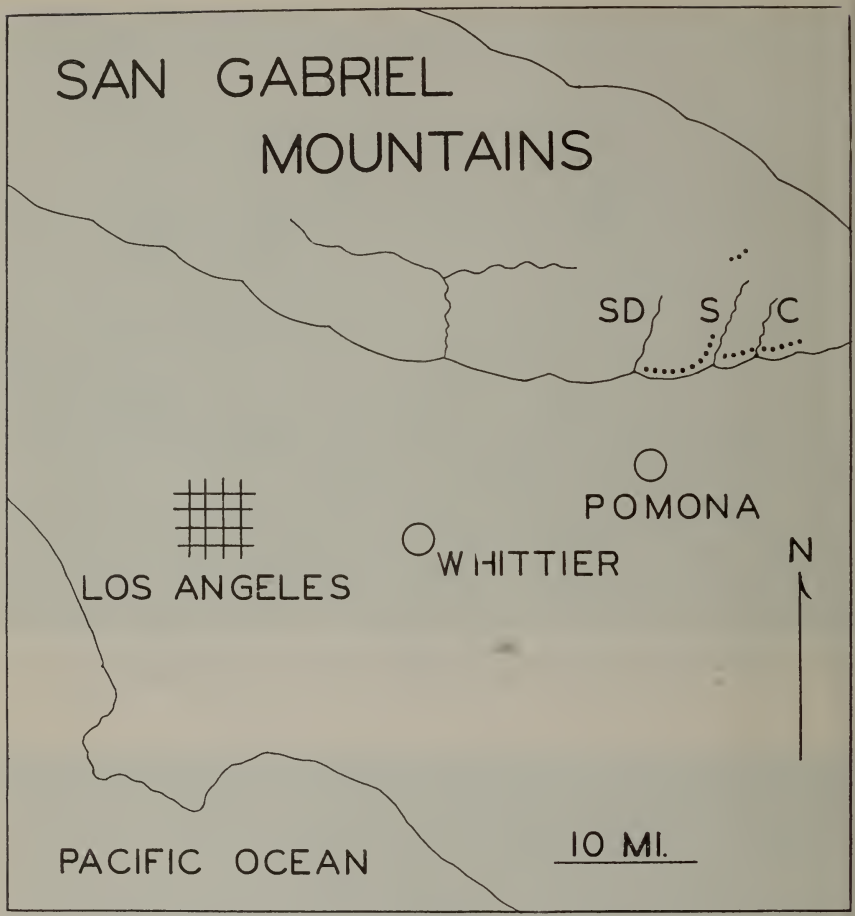

FIG. 5. Map showing locations of mylonite zones (. . . . .). S—San Antonio Canyon; SD—San Dimas Canyon; C—Cucamonga Canyon.

TYPES

The principal mylonite masses in the eastern San Gabriel Mountains are derivatives of granitic rocks (figs. 1, 2). Their general appearance is that of a foliated porphyry whose groundmass is greenish and aphanitic and whose phenocrysts are pink feldspar. This type grades into a dark-green, flint-like rock which has no phenocrysts or flow structure visible to the naked eye, but which is resolved by the microscope into a mylonite. The flint-like rock approaches the type called ultramylonite (Waters and Campbell, op. cit., p. 481). The pink feldspar is orthoclase with a 2V of approximately 50 degrees. Some of the grains are fractured and cut by quartz veinlets, and most of them are clouded with alteration products. Quartz is present as mottled groups of fine grains, each grain showing strain shadows and the group as a whole showing marked fluxion. The most important minor constituent is pale-green and faintly pleochroic chlorite that has

an index of refraction of 1.625, and no noticeable birefringence. Translucent particles of hematite are common, and titanite and calcite were observed.

An associated quartzite mylonite, somewhat glassy in appearance, has a faintly greenish luster and perceptible flow structure. Pink feldspars are sparsely distributed throughout the rock. Under the microscope the flow structure is accentuated by fine streaks of altered material. The feldspars are cataclastic and cloudy; quartz is minutely granular and shows pronounced strain shadows.

There are several types of mylonitized limestones. One is made up of alternating light and dark bands, both of which are cut by minute veinlets of calcite. The microscope resolves the bands into a thinly laminated mylonite or ultramylonite, the dark color of which is probably caused by graphite. Another limestone type (fig. 3) is light colored and shows lamination only on weathered surfaces. Microlenticular aggregates of quartz, plagioclase, and diopside are characteristic and show more or less clearly the effect of the milling process. The diopside is pale, clear green, resembling malacolite, the rare pure form reported from nearby Cascade Canyon and from the Crestmore quarries, California.[2] An additional characteristic mineral is a golden-brown biotite or phlogopite that shows slight pleochroism and an extremely small but noticeable 2V.

Particular attention is here called to a dark-gray mylonite containing porphyroclasts of albite that have irregular nuclei of orthoclase or possibly microcline (fig. 4). This relationship suggests that the albite is of metasomatic origin. If metasomatism was taking place at the same time as the mylonitization, some of the finer-grained portions of the rocks, where the texture is obscure, may be at least partially crystalloblastic rather than cataclastic.

DISTRIBUTION

The mylonites occur in several zones, shown roughly in fig. 5. One belt is high on the bold front of the mountains between San Dimas and San Antonio canyons. From Evey Canyon, a western tributary of San Antonio, the tectonic horizon curves northeastward into the main San Antonio Canyon, as shown in fig. 5. The general dip of the underlying contact, probably a thrust plane, is about 40 or 45 degrees to the northwest, and the zone of mylonitization is more than 100 feet thick (fig. 6). A second zone occurs near the base of San Antonio Peak, at the head of San Antonio Canyon, but here the attitude and thickness have not yet been determined.

By far the broadest mylonite zone follows the base of the mountains from San Antonio Canyon eastward for many miles. Cucamonga Canyon cuts across this zone, giving excellent exposures and showing a thickness of several thousand feet of northward-dipping, intimately associated mylonites, schists, and gneisses. Mylonites make up a large part of the section, and appear to grade into schists. Mylonites and crystalline rocks both are intruded by dikes of pegmatite and other plutonic rocks.

[2] Merriam, R., and Laudermilk, J. D., Two diopsides from southern California: Am. Mineralogist, vol. 21, pp. 715-718, 1936.

FIG. 6. Panoramic view of mylonite zone in Evey Canyon, showing about 2 miles of mountain front from the SSE. A mylonite band outcrops on the steep, bare slope midway up the mountain front.

The writer knows of no mylonite zones in western North America which are comparable in size to those of the San Gabriel Mountains. In the Appalachian region there are the pre-Cambrian mylonites near Philadelphia,[3] composed largely of cataclastic biotite, which have a maximum thickness of a quarter of a mile.

AGE

Structures in southern California are notably hard to date. However, because the mylonites of the eastern San Gabriel Mountains are cut by plutonic rocks which must be pre-Chico in age,[4] there is some basis for their age determination. Certainly the mylonites are older than the Tertiary and are at least as old as the Mesozoic batholithic intrusion. Whether or not this plutonism took place during the Cretaceous or the Jurassic or even earlier is still not determined (Woodford, op. cit., p. 257).

Speculation concerning the age of the San Gabriel Mountains has been voiced by a number of geologists. W. J. Miller[5] and G. J. Bellemin[6] consider them to be the chief source of the Tertiary clastic sediments, or at least of several of the conglomerates, in the Los Angeles Basin, a belief that implies the existence of the mountains throughout all or a large part of Tertiary time.

Since the discovery of mylonites in the bedrock, a re-examination of some of the Tertiary conglomerates from the Los Angeles Basin has shown that mylonites make up a small part of the Whittier Pliocene sediments and a considerable part of Pleistocene conglomerates on Garfield Avenue, 5 miles northwest of Whittier, and of Miocene conglomerates near Pomona (fig. 5). The coarse Miocene cobble beds are well exposed on the north side of the Pomona-Covina highway, opposite the Kellogg ranch house; they belong to the lower Puente formation (Lower Mohnian stage). Miocene cobbles, in particular, are identical to mylonites (or recrystallized mylonites) from the eastern San Gabriel Mountains and therefore tend to confirm the conclusions of Miller and Bellemin.

A remarkable characteristic of the mylonite constituents of the conglomerates is their resistance to the forces of disintegration, a property that makes possible their transportation to localities many miles from their place of origin.

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[3] Armstrong, Elizabeth, Mylonization of hybrid rocks near Philadelphia, Pennsylvania: Geol. Soc. Am. Bull., vol. 52, pp. 667-694, 1941.

[4] Woodford, A. O., Pre-Tertiary diastrophism and plutonism in southern California and Baja California: Proc. Sixth Pacific Sci. Cong., vol. 1, p. 256, 1939.

[5] Miller, W. J., Geology of the western San Gabriel Mountains of California: California Univ. at Los Angeles, Pub. Math. and Physical Sci., vol. 1, no. 1, 1934.

[6] Bellemin, G. J., Petrology of Whittier conglomerates, southern California: Am. Assoc. Petrol. Geologists Bull., vol. 24, pp. 666-669, 1940.

GEOLOGY OF THE SIERRA NEVADA NORTHEAST OF VISALIA, TULARE COUNTY, CALIFORNIA

By Cordell Durrell*

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INTRODUCTION

Location of the Area

The area described in this report is a part of the western slope of the southern Sierra Nevada in Tulare County, California. It embraces the lower drainage basin of the Kaweah River and its tributaries, extending about 12 miles eastward from the alluvium of the San Joaquin Valley nearly to the western boundary of Sequoia National Park.

Topography and Physiography

The relief of the region is rugged, ranging from an elevation of about 500 feet near the margin of the San Joaquin Valley, to over 5000 feet on the west end of Ash Peaks Ridge only 12 miles distant. Many of the initial mountain slopes rise more than a thousand feet above the adjacent alluvium of the valley floor. The walls of the principal canyons rise in places more than 2000 feet above the level of the streams.

The drainage pattern is dendritic and, except in the northwestern part of the area, is entirely tributary to the Kaweah River and its several principal branches. The landscape is in a condition of early maturity, and it consists of an intricate pattern of minor streams separated by steep and sharp-crested ridges.

The only stream terraces in the region are along the lower courses of Dry Creek, the Kaweah River, and the South Fork of the Kaweah

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River. Those developed along the two first-mentioned streams are all close to the present stream level, and are the normal result of lateral erosion in combination with down-cutting. The alluviation of the South Fork of the Kaweah, upstream from the narrows a mile southeast of Three Rivers, was due to the local base level constituted by very resistant hornfelses exposed in the narrows. Recent downcutting of that barrier has left the alluviated area as a terrace.

Several highland areas of low relief may conceivably represent remnants of an earlier erosion cycle, but proof that they do so is wanting. Such areas include Quail, Adams, and Shadley Flats in the northwestern part of the map area, Manikin Flat near the center of the map, and Little Oak Flat near the center of the southern margin of the map.

Several large topographic recesses, without prominent interior drainage lines, occur along two of the main streams. These are Washburn Cove and Shepherd Cove, north of Three Rivers, and a similar unnamed feature 2 miles east of Three Rivers on the north side of the South Fork. These peculiar depressions seem to owe their origin to the lesser resistance to weathering and erosion of the rocks which floor them.

Most of the map area consists of grass lands with a light forest of oak, but the northeastern part is brushy in many places. The soil cover is heavy over most of the area but exposures are satisfactory except for the most detailed kind of geologic mapping. Roads are plentiful in the western part, but to the east and northeast the great ridges between the major streams are accessible only on foot or by horse.

Previous Work

When the author first started to work in this region in 1932, no geologic maps of this area nor of adjacent areas were in existence. Henry W. Turner [1] had devoted a little more than one page to observations made while passing through the region. A physiographic study of the southern Sierra Nevada by Hake [2] includes this area. Mapped areas nearest to this include the Mineral King district 20 miles to the east, mapped by Knopf and Thelen,[3] the Kernville quadrangle, 35 miles to the southeast, mapped by Webb,[4] and the foothill region between the Kings and San Joaquin rivers, 20 miles to the northwest, mapped by Macdonald.[5]

The work by the present author was done during the years 1933 to 1936, and was published in 1940.[6] This earlier paper describes in detail the petrology and petrography of the area with particular emphasis on the metamorphism. The reader is referred to that work for a more comprehensive treatment of those fields than is included here.

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[1] Turner, H. W., Further contributions to the geology of the Sierra Nevada: U. S. Geol. Survey, 17th Ann. Rept., pt. 1, pp. 714-715, 1895-96.

[2] Hake, Benjamin, Scarps of the southwestern Sierra Nevada: Geol. Soc. America Bull., vol. 39, pp. 1017-1030, 1928.

[3] Knopf, A., and Thelen, P., Sketch of the geology of the Mineral King district: California Univ., Dept. Geol. Sci., Bull., vol. 4, pp. 227-262, 1905.

[4] Webb, R. W., Descriptive geology of the Kernville quadrangle: California Div. Mines Rept. 36, pp. 343-378, 1940.

[5] Macdonald, G. A., Geology of the western Sierra Nevada between the Kings and San Joaquin rivers, Calif.: California Univ., Dept. Geol. Sci., Bull., vol. 26, pp. 213-286, 1941.

[6] Durrell, C., Metamorphism in the southern Sierra Nevada northeast of Visalia, Calif.: California Univ., Dept. Geol. Sci., Bull., vol. 25, pp. 1-118, 1940.

This present work includes no new results, and is undertaken only to make the general geological features and history more readily available. The motive for this republication is the recent discovery in the region of the ores of tungsten. Small amounts of manganese are also known to occur. It is hoped that the present writing may be of more value to the prospector and mine operator than the earlier one.

The accompanying map includes parts of the Dinuba, Tehipite, and Kaweah quadrangles, and the whole of the Lemon Cove quadrangle, an area of about 350 square miles. The geology of the Rocky Hill quadrangle, which is included in the earlier work[7] has been omitted because it is of less economic interest.

DESCRIPTIVE GEOLOGY

All of the rocks of the area herein described, excepting only the alluvium, belong to the "bedrock complex" of the Sierra Nevada, and are of pre-Cretaceous age. They were involved in, or resulted from, the Nevadan revolution which occurred in the Upper Jurassic.[8]

The rocks of the region may be divided into two groups: (a) the sedimentary and igneous rocks which were folded and metamorphosed during the Nevadan revolution; and (b) the plutonic igneous rocks which were intruded immediately after the folding.

The first group is a thick series of sedimentary, pyroclastic, and volcanic rocks called the Kaweah series,[9] and many igneous intrusive bodies of approximately the same age. All of these sediments and igneous rocks were folded and metamorphosed at the time of the Nevadan orogeny. The Kaweah series is further divided into four stratigraphic units.

The second group of rocks consists of plutonic intrusives which range in composition from hornblende gabbro to granite. The hornblende gabbros are shown separately on the map. All others are shown as a single unit though many separate intrusions are present.

Since the Nevadan revolution the southern Sierra Nevada has been predominantly subject to erosion, and during this long interval of geologic time a great but unknown thickness of metamorphic rocks has been stripped away. Only the lowest portions of the metamorphic rocks now remain. These appear on the map as elongated but irregular bodies surrounded by and embedded in plutonic igneous rocks. Such bodies are known as roof pendants. All available evidence indicates that the bodies were attached to a once-continuous roof of metamorphic rock. They are bodies in place.

Kaweah Series

The Kaweah series consisted originally of a great complex of sedimentary, pyroclastic, and volcanic rocks. These have suffered metamorphism varying from place to place in kind and intensity. Further complexities arise out of the fact that rocks, originally different in origin but similar in composition, become similar in all respects when metamorphosed under the same conditions. The rocks resulting from the metamorphism are highly diversified.

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[7] Durrell, C., *op. cit.*

[8] Taliaferro, N. L., Geologic history and correlation of the Jurassic of southwestern Oregon and California: Geol. Soc. America. Bull., vol. 53, pp. 71-112, 1942.

[9] Durrell, C., *op. cit.*, p. 13.

The same rock types occur throughout the whole extent and thick ness of the Kaweah series, but not everywhere in the same relative pro portion. The fourfold division of the series is based upon the pre dominance of certain types of rocks in each of the four parts. Thes four divisions have only arbitrary boundaries, and it appears that tw are in part the equivalent of the remaining two. The total thickne of the Kaweah series is approximately 15,000 feet. The sum of the fou units is greater than this because of the equivalences mentioned abov

Yokohl Amphibolite

The Yokohl amphibolite, which is the oldest member of the Kawea series, is best developed in the Rocky Hill quadrangle, south of the are described in this report. On the present map it occurs only on Wood lake Mountain and on a small hill immediately to the north.

The section on Woodlake Mountain consists of nearly 8000 feet o plagioclase amphibolite derived principally from basalt lava flows, tuff and breccias. Local thin bands of talc, chlorite, and hornblende schis are present. Amygdaloidal structures, breccia structures, and porphy ritic textures are clearly evident. The higher part of the section, ea of the summit of the mountain, contains a few thin layers of muscovi schist derived from rhyolite tuffs.

Four thin sills of serpentine, including some talc and chlorite schis and meta-gabbro occur near the summit of the mountain. These we not mapped because of poor exposure. Intrusions of serpentine an gabbro do not occur any higher in the Kaweah series. Extensive bodi of them occur in the Yokohl amphibolite in the Rocky Hill quadrang and these have been described in the earlier report on this area.[10] Pillo structures in flows, bedded tuffs and quartzites derived from radi larian cherts, interbedded with the Yokohl amphibolite in the Rock Hill quadrangle, show the submarine origin of the stratified rocks.

Lemon Cove Schist

The Lemon Cove schist, which is in part equivalent to, and in pa younger than the Yokohl amphibolite, occurs in three belts. The large area is that along Dry Creek where the schist is folded into the D Creek anticline. It is also exposed along Sheep Creek, which is trib tary to the North Fork of the Kaweah, in the core of the Sheep Cre anticline. A narrow belt follows the eastern margin of the Kawe series between Yucca Creek and Eshom Valley, and dips west under t Sheep Ridge syncline.

Quartz-muscovite-biotite schist and phyllite are the most abunda rock types. These were derived principally from the metamorphis of silicic tuffs with various degrees of admixture of fine sediment. Alo the lower course of Dry Creek and westward toward Woodlake Mou tain the original character of these rocks may be clearly seen. Flatten lapilli, probably originally pumiceous, are set in a darker more rich micaceous matrix. Phenocrystic crystals and fragments are abunda Occasionally undistorted originally igneous rock fragments may found. Where more highly metamorphosed, the originally tuffaceo rocks are finely banded and gneiss-like.

Fine mica-rich, often graphitic phyllites derived from argillaceo sediments occur east of the lower course of Dry Creek. Immediat

[10] Durrell, C., *op. cit.*, p. 15.

east of the axis of the Dry Creek anticline, and extending northwest for about 3 miles from its southern termination at the Kaweah River, is a quartz-mica schist derived from fine sandstone and siltstone. This massive but obviously bedded unit has a maximum thickness of about 400 feet. To the north it becomes finer grained and grades into phyllites through decrease in grain size.

Muscovite schists, and light-colored muscovite-bearing, but nonschistose rocks derived from rhyolite flows, tuffs, dikes and sills are more abundant in the Lemon Cove schist than in any other division of the Kaweah series, but they represent only a minor fraction of the whole. They are most abundant in the lower part of the section, particularly in the area east of Woodlake Mountain. A few feet above the top of the Yokohl amphibolite there is a metamorphosed rhyolite, evidently a flow about 20 feet in thickness, which is crowded with dipyramidal quartz phenocrysts up to 4 mm in diameter. This flow may be traced through a sinuous outcrop for about 2 miles. It is repeated on the east limb of the syncline which lies east of Woodlake Mountain. Many of the metamorphosed rhyolites are massive and fine grained, and their exact origin is not clear. When schistosity is lacking they may easily be confused with much younger aplite dikes.

A sooty black to silky black garnetiferous biotite-oligoclase schist occurs on both flanks of the Dry Creek anticline, extending from the Homer Ranch to the East Branch of Dry Creek. This rock is believed to represent a metamorphosed slightly alkaline volcanic rock. No comparable rocks have been found elsewhere in the area.

The second most abundant group of rocks in the Lemon Cove schist includes quartzite, and quartz schist. These rocks occur in lenticular masses up to several hundred feet in thickness, and a mile or more in length. Within each lens the rocks are bedded in layers ranging from a fraction of an inch to several inches in thickness. A still finer banding is often present. Between the thicker quartz-rich layers are thin partings of different composition.

These quartz-rich rocks are of two principal types, but all transitions between them may be found. One type contains ferruginous and calcareous impurities represented by such minerals as magnetite, amphiboles, epidote, zoisite, and garnet. The partings between the quartzite layers consist in some cases of thin streaks of magnetite, but more commonly of muscovite-biotite schist representing original argillaceous sediment. Manganiferous beds have been converted to quartz-rhodonite rocks, and manganese oxide stains resulting from weathering are common. Graphite is commonly present and represents original organic material.

These rocks are to be found everywhere in the Lemon Cove schist but are most abundant in the lower part, along the lower course of Dry Creek and westward toward Woodlake Mountain. They are commonly closely associated in the field with amphibolites derived from basalts. The color is most commonly light, but black, purple, and dull reddish-brown rocks are present. Identical rocks are very common in the Yokohl amphibolite in the Rocky Hill quadrangle.

The second rock group is similar in structure, in that it occurs in thin units aggregated into larger lenses. These rocks, however, are micaceous, contain both muscovite and biotite, and constitute micaceous

quartz schists. The partings between the larger quartz-rich layers consist of muscovite schist, muscovite-biotite schist or graphite-rich mica schists. Types transitional to these two groups contain both amphiboles and mica.

These rocks are, in their larger aspects and occurrence, similar to the radiolarian cherts of the Franciscan [11] of the Coast Ranges of California, and there can be little doubt they were originally like them in all respects including their origin.

Plagioclase amphibolites and hornblende schists derived from basalt flows and tuffs are abundant in the Lemon Cove schist, particularly along the lower course of Dry Creek, and westward to Woodlake Mountain. In many places, notably near the mouth of Yucca Creek, finely banded rocks consisting of alternating bands of hornblende-rich and plagioclase-rich amphibolites are abundant. These are metamorphosed interbedded basaltic tuffs and impure limestones. Phenocrysts and amygdules may often be recognized among the rocks representing flows.

Marbles derived from limestone are not abundant in the Lemon Cove schist, but occur in all of the three principal areas. A single thin bed, exposed on both flanks of a minor syncline, occurs east of the lower course of Dry Creek and at the Kaweah quarries. The most extensive limestones in the Lemon Cove schist occur along Dry Creek from a mile south of Elder Creek to the northwestward. These have suffered strong contact metamorphism. A few thin and impure limestones occur along Sheep Creek and the North Fork of the Kaweah. Where least metamorphosed the marbles are dull gray and fine grained, thinly bedded and quite impure. More intense alteration results in a coarsening of the grain and lightening of the color, which eventually becomes white. Micas and tremolite result from the recrystallization of impurities.

The thickness of the Lemon Cove schist is about 8000 feet, but almost half of this is thought to be equivalent to the upper part of the Yokohl amphibolite.

Homer Quartzite

The Homer quartzite is younger than the Lemon Cove schist and rests conformably upon it. This division of the Kaweah series consists largely of quartzite and quartz schist derived from chert. Thick and extensive lenses comprised of many thin beds are separated by large units of mica schist and phyllite, often rich in graphite. In detail the rocks are like those of the second group of quartz schists derived from the cherts described herein under the Lemon Cove schist; only minor amounts containing calcareous and ferruginous impurities are present. Much of the rock between the larger quartzite lenses is also quartz-rich and much of it is rich in graphite. These rocks represent pelitic clastic sediments and siliceous and organic shales.

Mica schists derived from silicic tuffs are far less abundant than in either the Lemon Cove schist or Three Rivers schist, but do constitute an important part of the unit. In the Bear Mountain area such schist becomes the dominant type: the quartzites lens out in that direction. Here the Homer quartzite resembles both the Lemon Cove schist and

[11] Davis, E. F., The radiolarian cherts of the Franciscan group: California Univ. Dept. Geol. Sci., Bull., vol. 11, pp. 235-432, 1918.

he succeeding Three Rivers schist, but is neither so rich in amphibolite s is the former, nor in marble as is the latter.

Muscovite schists derived from rhyolites and rhyolite tuffs occur s thin beds in the Homer quartzite.

Amphibolites, probably mostly derived from basaltic tuffs, are relaively rare.

Marbles occur only in a few thin and short beds.

The thickness of the Homer quartzite is about 7000 feet.

Three Rivers Schist

The Three Rivers schist comes into contact with the Homer quartzite or only a short distance and there it is seen to overlie the Homer. However, the larger portion of the unit as seen along Sheep Creek and on he north side of Sheep Ridge is believed to be equivalent to the Homer quartzite. The detached areas in the vicinity of Three Rivers are correlated with the main body to the north on the basis of lithologic similarity nd position.

The rocks of the Three Rivers schist need not be described in detail s they are identical to those of the Lemon Cove schist. They differ, owever, in relative abundance.

The most abundant rock type is mica schist derived from silicic uffs intermixed with fine sediments. These are mostly banded and neiss-like due to greater intensity of metamorphism than is attained n much of the Lemon Cove schist.

The second most abundant rocks are the marbles and various contact metamorphics derived from pure to impure limestones. A few of hese are shown on the accompanying map, but not all were mapped.

Quartzites, muscovite schists, and amphibolite are far less abundant han in the Lemon Cove schist. Mica-rich schists derived from argillaceous sediments, while not constituting a large fraction of the unit, re more abundant than in the Lemon Cove schist.

The thickness of the Three Rivers schist is about 10,000 feet, but very likely the lower 7000 feet is equivalent to the Homer quartzite. The original thickness, however, is not known as the top is not present.

Age of the Kaweah Series

The age of the Kaweah series will probably remain unknown until fossils are found in it. The author has carefully searched for them in places most favorable for their occurrence, but none could be found. A Triassic age was suggested [12] on the basis of lithologic similarity to the Mineral King beds, which constitute a roof pendant some 20 miles to the east. The Upper Triassic age of the Mineral King beds was established on the basis of fossils found there by the writer and Mr. Henry Lindbloom. They were identified by Dr. S. W. Muller.[13]

Plutonic Rocks

The plutonic rocks, which cover the greater part of the mapped area, range in composition from hornblende gabbro to granite, and minor variants extend to still greater extremes. Variation in composition within individual intrusions is not large except in the hornblende gabbro. The mineral composition and texture are for the most part simple. Satellitic dikes are common.

[12] Durrell, C., *op. cit.*, pp. 16-20.
[13] Durrell, C., *op. cit.*, p. 17.

Two divisions have been made in mapping these rocks. The distinction is based on the presence or absence of quartz in essential amounts, and color may generally be used as an index of the amount of quartz present. Rocks which contain no quartz, or only minor amounts, are dark colored; whereas those with essential quartz are light colored. The first group is designated as hornblende gabbro, and the second as quartz-bearing plutonic rocks.

The area of plutonic rocks is comprised of a number of relatively small intrusions. While the quartz-bearing intrusions have not been subdivided in the mapping, at least eight separate bodies are known. Their approximate distribution is mentioned below.

Hornblende Gabbro

Six distinct bodies of hornblende gabbro are shown on the map. The small area south of the East Branch of Dry Creek is to be considered as a part of the larger body to the north and east of it. Each of the six bodies is probably a separate stock; with the exception of the area in the extreme northwest which extends beyond the limit of the map and which is known to be complex.

Each of the several bodies exhibits many textural varieties. Rapid variation in grain size is a characteristic feature, the grain size ranging from medium to very large, single crystals of hornblende reaching a length of 6 or 7 inches in pegmatitic facies. Variations in the habit of the hornblende, which is sometimes needlelike, sometimes prismatic and sometimes equidimensional, produce other varieties. A coarse banded structure, produced by alternations in grain size and texture, is widespread.

The relative amounts of hornblende and plagioclase vary widely and are subject to variation in thin bands. Minor dioritic facies are often very light colored. Hornblende increases to become the sole constituent in many places. Augite, hypersthene, and biotite are common accessory minerals. Quartz is present in small amount in many specimens; olivine has not been detected in any specimen.

Quartz-Bearing Plutonic Rocks

Most of the area is comprised of quartz diorite. Quartz monzonite is second in abundance, and granodiorite occurs only in small amount. Granite is represented only in the eastern border area.

With the exception of one body of quartz diorite, all are very light colored, except in minor border facies, and are rich in quartz.

The large area on the western border of the map, west of Dry Creek and south of Bear Mountain, is mostly light-colored biotite-quartz diorite. Granodiorite occurs along the eastern margin near Dry Creek, and pyroxene-quartz diorite occurs along the west side. Whether this is a complex of intrusions, or whether these variants are only facies of the biotite-quartz diorites, is not known.

The Shadequarter Mountain area consists predominantly of rather coarse hornblende-biotite-quartz diorite. Local increases in potash feldspar give rise to granodiorite, but this seems to be only a facies difference.

The area southeast of Manikin Flat and extending across the Kaweah River to Horn Mountain and Cahoon Mountain is also hornblende-biotite-quartz diorite.

The Ash Peaks-Yucca Mountain area consists of a coarse-grained biotite granite, but this is separated from the metamorphic rocks by an elongated body of medium-grained biotite-quartz monzonite. This body widens toward the north to include Burnt Point; on the south it includes and extends south of Shepherd Peak.

The area west of Three Rivers, which extends northwestward across Greasy Creek, is composed of two intrusions. The contact between them strikes northwestward and divides the area into two approximately equal portions. Both bodies extend southeastward across the Kaweah River, but their extent in this direction is unknown. The body on the northeast is a rather dark-colored augite-hypersthene-biotite-hornblende-quartz diorite. The southwestern part of this area is composed of a light-colored gneissic biotite-quartz monzonite with conspicuous accessory red garnet.

To the north, east, and south of Lemon Cove is quartz diorite.

Satellitic Dikes

The margins of the plutonic bodies are zones of dike injection. Most of the dikes have essentially the same composition as the adjacent bodies. Differentiated dikes are quite abundant but are simple in composition. Aplite, lamprophyre (malchite and kersantite), and pegmatite dikes occur in both the plutonic rocks and the metamorphic rocks. Aplites are conspicuous, but lamprophyres weather so easily that they are seldom seen. The pegmatites are small and simple in composition and consist almost entirely of quartz, feldspar, biotite, muscovite, and tourmaline.

STRUCTURAL GEOLOGY

The geologic structure of the region is the result of two different processes acting at two different times. Both are consequences of orogeny, and the time difference is small with a possible overlap. The earlier structures are internal to the Kaweah series, and resulted from the compression of the sediments and igneous rocks comprising it. The second set of structures resulted from invasion by the plutonic igneous bodies; they are in part dependent upon the earlier structures.

Structures Internal to the Kaweah Series

The determination of structure in this region was a matter of considerable difficulty for many reasons. Steep dips and local overturning combined with pronounced hill creep and thick soil lend difficulty to the determination of attitude. No original structures were found to assist in a proper determination of position. Lenticularity, lack of distinct horizons, and absence of fossils made it necessary to determine structure and stratigraphy together; neither problem could be independently solved. Lack of continuity due to igneous invasion, and the varying intensity of metamorphism are further difficulties. For these reasons, the structural picture presented may not be the true one, though the principal features are certain. The stratigraphy may be in error to the same extent as the structure. The reasoning which has lead to the present concept has been fully presented elsewhere,[14] and is not repeated.

Steep dips, mostly 70° to 90°, are the rule, and local overturning occurs. In spite of the closeness of folding, there are apparently no

[14] Durrell, C., *op. cit.*, p. 20.

large overturns. Small-scale folding is not common except in the immediate vicinity of the axes of the major folds. Here the beds are usually bent sharply back, or are closely plicated in a series of folds with amplitudes of only a few feet, within a zone only a hundred feet in width. The limbs of the great folds are strikingly uniform in dip, and lack minor folds and plications.

Immediately east of the lower course of Dry Creek is the axis of the Dry Creek anticline which plunges north at a low angle. Puckering of the beds in the axial region may be seen at a number of places.

West of the Dry Creek anticline is a small syncline, determined through the mapping of a marble lens, shown on the map. The dip of the marble lens is steep, even at the south end where it closes about the end of the syncline.

East of Woodlake Mountain is a small syncline determined by mapping a meta-rhyolite flow. The failure of the Yokohl amphibolite to be repeated on the east limb of this syncline is the reason for the assumption of equivalence between the upper part of that unit and the lower part of the Lemon Cove schist. The latter contains a number of amphibolites derived from basalts in that part of the section.

The region between these two synclines is an area of crumpling, apparently representing the region of convergence of a number of large folds now lost through granitic invasion.

South of the Buzzards Roost, in the Lemon Cove schist, is an anticlinal nose, en echelon with the Dry Creek anticline, which plunges south. This fold is immediately cut off on the north by an igneous contact.

A syncline shown in the Bear Mountain area is predicated on very poor evidence.

Along Sheep Creek is an anticline in which beds believed on lithologic grounds to be the Lemon Cove schist are exposed. To the northeast of this, through Sheep Ridge, is a syncline which brings the Lemon Cove schist to the surface farther to the northeast.

Between Sheep Creek and Dry Creek there must be a synclinal axis, but igneous rocks occupy almost all of that region. Where the metamorphic rocks do continue across, contact metamorphism is so intense that no conclusive evidence could be obtained.

The detached areas to the northwest and southeast of Three Rivers are folded, but nothing is known of the structural details.

No evidences of important faulting have been found, but in view of the necessity of determining structure and stratigraphy together, faulting may have passed undetected. Several small faults forming the locus of deposition of quartz veins are present, but these are probably later in age than the main period of deformation during which the folded structures were produced.

Structural Relationships of the Plutonic Intrusives

The contacts between the several plutonic bodies have not been mapped, except for the boundaries of the hornblende gabbro. From the descriptions previously given, however, it is apparent that the form of these bodies, in plan, varies from roughly elliptical to elongate. The hornblende gabbros are the earliest members of the series, as dikes of quartz-bearing plutonics cut them at all contacts, and angular inclusions of the former occur in the latter. The latter fact shows that the

hornblende gabbros were solid before the intrusion of later members. Whether or not this is true for all members of the series is unknown. Meager evidence suggests that the sequence, begun with hornblende gabbro, which is the most basic member, progressed toward the more silicic end with the passage of time. This is in agreement with the observations of Knopf [15] and of Mayo [16] for the eastern Sierra Nevada. No evidence of chilling at the contacts has been found.

The contacts between the Kaweah series and the plutonic intrusives may be seen on the map to be partly dependent upon structures within the Kaweah series. The general elongation of the intrusions parallel to the strike of the metamorphics was undoubtedly developed under the influence of bedding and cleavage. On the other hand, the plutonic contacts truncate both anticlinal and synclinal folds, and for large distances contacts cross the bedding at high angles. From this it is clear that intrusion post-dated folding, and that the Kaweah series was not further deformed as a result of intrusion.

The contacts as placed on the map are in part arbitrary, and represent a border zone of injection. The metamorphic rocks usually are intruded by apophyses or dikes for a distance up to a quarter of a mile. These minor injections are mostly parallel to the bedding and schistosity, or at about right angles to it in a steeply dipping plane. The plutonic bodies in the zone adjacent to the contact contain abundant inclusions of the metamorphics, and many of these reach dimensions of hundreds or even thousands of feet. It is thus impossible to delineate an exact contact between igneous rock and metamorphic rock in place.

With minor exceptions actual surfaces of contact between the two rock types are sharp. Due to the complex character of the contact region, contact surfaces may have any attitude.

Examination of the contact zone through a vertical range of several hundred feet shows that the contacts in general dip steeply under the metamorphics, and this is clearly shown on the map. Most contact zones dip at about 65°, and the extreme range is from 45° to 70°. The floor of the roof pendant is nearly flat, however, and the change from dipping wall to flat-lying floor seems to be abrupt.

The flat-lying floors of the metamorphic bodies are exposed in many places, notably in the vicinity of Three Rivers and about Antelope Valley. These relationships are shown on the cross-sections. Plutonic bodies at no great depth are elsewhere indicated by contact metamorphism at relatively great distances from exposed contacts.

The character of the contacts as described above indicate that the plutonic rocks were emplaced by stoping, but local zones of intrusion breccias and injection gneisses indicate that assimilation may have played a part in the emplacement process at an earlier time.

METAMORPHISM

The character of the metamorphism and the metamorphic rocks has been fully presented in the author's earlier work on this district,[17] and will not be repeated herein.

[15] Knopf, A., and Kirk, E., A geologic reconnaissance of the Inyo Range and the eastern slope of the Sierra Nevada: U. S. Geol. Survey, Prof. Paper 110, p. 72, 1918.
[16] Mayo, E. B., Some intrusives and their wall rocks in the Sierra Nevada: Jour. Geology, vol. 43, p. 679, 1935.
[17] Durrell, C., *op. cit.*

The metamorphism can best be treated under two headings: dynamothermal metamorphism, the result of stress and elevated temperature; and contact metamorphism, resulting from heat from the intrusive plutonic bodies. The latter usually followed and was superimposed upon the former. It has been shown by the author, in the work cited above, that the two types of metamorphism are, in this area, not clearly separable, and are, in fact, different manifestations of a single set of phenomena. It is believed that the heat involved in both types of metamorphism was derived from the plutonic intrusives, and that where it was effective in conjunction with residual orogenic stress, dynamothermal metamorphism resulted. Where the heat acted in the absence of stress, contact metamorphism in the strict sense was produced. The latter situation was largely dependent upon the form of the magma bodies. Superposition of contact metamorphism upon dynamothermal metamorphism came about with the passage of time through enlargement of the magma chambers.

Greatest emphasis is placed upon the contact metamorphism because of the economic importance attached to it. Recent discoveries of scheelite, one of the principal ore minerals of tungsten, in the zones of contact metamorphism of this area have led to new activity and interest in the district.

Dynamothermal Metamorphism

The rocks of the Kaweah series already described are the result of dynamothermal metamorphism. These constitute the greater part of the Kaweah series, and are modified to a greater or lesser extent by contact metamorphism only along the margins of plutonic bodies. The antecedents of each rock type produced by the dynamothermal metamorphism have been indicated.

Recrystallization under stress and increased temperatures has resulted in schistosity, which is best developed in rocks capable of yielding micas or micaceous minerals in large quantities; but even in these the schistosity is far from perfectly developed. Other rock types are still less perfectly schistose, but the orientation of minerals is evident in most, and can be seen even in some of the marbles.

In general the schistosity is parallel to the stratification and sometimes follows the bedding on crests and troughs of folds. Transgression of the schistosity across the bedding is developed only locally and then in thick, homogeneous, originally incompetent rocks. Such relations may be seen in the mica schists derived from silicic tuffs in the area between Dry Creek and Woodlake Mountain where severe crumpling occurred.

The dynamothermal rocks are all quite fine grained, but the grain size systematically increases as the contacts of the plutonic intrusives are approached.

Contact Metamorphism

The intensity of contact metamorphism varies with the kind of rock and with position. In general, it is most strongly developed along the flat floors of the roof pendants, and at low elevations on the walls of them. The conspicuousness of the contact metamorphism varies with the composition of the rock, being most obvious in carbonate rocks, or in those

which originally had a considerable content of calcium carbonate. The contact metamorphic effects gradually fade out with increasing distance from the contact, but generalizations as to the thickness of the contact zone are scarcely possible because of the variation in intensity with position. Along some of the contacts at high elevations, such as those south of Manikin Flat, contact phenomena are almost entirely lacking. Elsewhere the zone of contact metamorphism is several hundreds of feet thick. The width of zone shown on the map is not the thickness of the zone, but is dependent upon that, the dip of the contact, and the topographic configuration within the zone.

In view of the recent economic interest in this area, an approximate outline of the zone of contact metamorphism, where rocks originally limestones are known to be present, is indicated on the accompanying map. Unfortunately, only a few of the carbonate rocks, which are likely to be of economic importance, were mapped, but such rocks may be expected anywhere that the Three Rivers schist is in contact with plutonic rocks, and elsewhere where contact metamorphism is indicated on the map. The limits of the zone as shown on the map are not exact, but will probably include most of the area that is of economic interest, though exceptions are to be expected.

The changes induced in rocks by contact metamorphism are in part structural. The first evidence is usually a hardening of the rock and an attendant loss of cleavage. In some cases, larger, conspicuous crystals appear. In the most intense recrystallization, all trace of schistosity is lost, and the rocks become extremely hard and often flint-like hornfels.

Quartz hornfels, or quartzite, is produced from the quartz schists which often contain visible crystals of graphite.

Feldspar-rich quartz-biotite hornfels is derived mostly from the schists which were originally silicic tuffs. Schists richer in mica yield large crystals of andalusite, and in extreme cases, cordierite-garnet-andalusite hornfels. The last-mentioned type occurs along the South Fork of the Kaweah River near the bridge about a mile southeast of Three Rivers.

The hornblende-plagioclase schists and plagioclase amphibolites develop diopside in contact metamorphism. A few more basic types have recrystallized with the formation of hypersthene and green spinel. In the hand specimen these changes may be detected through the development of a light green color and loss of schistosity. The development of pyroxene occurs first in the more plagioclase-rich portions of the rock. Similar changes occur in the amphibolites derived from gabbro on Woodlake Mountain.

Carbonate Rocks

Originally pure limestones have recrystallized to white marble in which the grain size varies from fine to very coarse. Rocks in which the only impurity was organic material, now contain graphite in thin flakes scattered through the calcite. Rocks of this type are abundant throughout the contact zones of the area, and are often interbedded with rocks of more complex mineralogy.

A marble bed in the Lemon Cove schist along Dry Creek, where it turns northeastward across the metamorphics at the southeast base of Bear Mountain, was originally dolomitic. Scattered through the calcite

are crystals of forsterite, diopside, and a little chondrodite. Talc, ser-pentine, and brucite are present as secondary minerals.

Great diversity of mineralogy is present in the calcsilicate horn-felses derived from impure limestones. A complete list of the minerals and mineral assemblages is given in the publication previously men-tioned.[18] The original rock types among this group range from lime-stones with small amounts of impurities to marls, and highly siliceous rocks which represent replacement cherts. The hornfelses range from nearly pure calcite rocks to those of nearly pure quartz. Intermediate types are various mixtures of calcite or quartz and lime silicates, many consisting largely of the latter. Wollastonite, diopside, grossularite and plagioclase are the principal lime silicates. Scapolite, idocrase, and zoisite are also present, and their hydrous character indicates the influ-ence of water in metamorphism. Phlogopite is common, usually in rocks originally rich in clay. It is associated with orthoclase and an abund-ance of diopside. Hornblende is present in rocks representing mixtures of calcium carbonate and basaltic tuff.

Orthoclase, magnetite, pyrite, sphene, and graphite are often presen with the lime silicates.

Throughout most of the contact zones of the area, the grain size o these rocks is not exceptionally coarse, and the silicates are disposed in bands often only a fraction of an inch in thickness. Interlaminated bands of nearly pure calcite marble are often present. Such relation indicate clearly that the composition of these rocks has not been change during the metamorphism. It may be stated with assurance that suc rocks were originally impure, and the present banding represent original stratification.

In areas of most intense contact alteration there are rocks in whic the grain size reaches dimensions of several centimeters, and all trac of small-scale banding or stratification are lost. Here the metamo-phism has probably involved the introduction of such substances a silica and magnesia from magmatic sources. The local occurrence o scapolite, phlogopite, and idocrase, which probably originated unde such conditions, may be taken as strong indication of the introductio of chlorine and fluorine. It is not unreasonable to expect the introdu tion of silica, iron, and magnesia as well, though this has not yet bee proven in this district.

Garnet Zones

Among rocks which may have originated in the manner mentione above are those composed of garnet, epidote, and quartz. Scheelite, th ore of tungsten, is most likely to be found in rocks of this characte Rocks of this type occur locally along the contacts of limestones ar plutonic intrusions in several places. They are most strongly develope in the vicinity of Three Rivers. The area immediately east of Thr Rivers, including the slopes of the steep mountain known locally Blossom Peak, contains many outcrops of garnet-rich rocks. South Three Rivers, on the south side of the South Fork of the Kaweah Rive are other occurrences. Similar rocks also occur along the west ba of the Kaweah River opposite Three Rivers.

[18] Durrell, C., *op. cit.*, p. 58.

Garnet zones also occur along the contact between Shepherd Peak and Advance, and farther to the north toward Yucca Creek. They are less well developed in the valley of Sheep Creek. North and west of the headwaters of Sheep Creek, and extending across to the East Branch of Dry Creek, are numerous outcrops of garnet-rich zones in an area of very intense contact alteration.

Along Dry Creek, for about 2 miles northeast of Elder Creek, and for about 1½ miles south of Elder Creek, the Lemon Cove schist contains several rather thick limestones all intensely altered by contact metamorphism. Garnet-rich zones are not so abundantly developed here as elsewhere, but they are present.

All of the occurrences mentioned above fall within the limits of contact metamorphism as shown on the accompanying map. This discussion is expected to serve only as a general guide and other areas of contact metamorphism should also be examined for possible occurrences of minerals of economic importance.

SUMMARY OF GEOLOGIC HISTORY

The geologic record in this district begins with the accumulation, in a marine environment, of the basic lava flows and tuffs, interbedded radiolarian cherts, and minor clastic sediments that later became the Yokohl amphibolite. This is believed to have been closely followed by the intrusion of sills of diallage gabbro and peridotite. The peridotite was converted to serpentine immediately after emplacement and crystallization.

Basic volcanism waned and was succeeded by the eruption of more silicic volcanic types, chiefly silicic tuffs. Interbedded with the tuffs were fine clastic sediments, cherts, and lava flows, both silicic and basic, and a few limestones. The injection of small dikes and sills accompanied volcanic activity. This series became the Lemon Cove schists.

Deposition of the original cherts and siliceous and organic shales of the Homer quartzite followed the eruption of the silicic tuffs. Volcanic activity became less intense, but both silicic and basic types continued to be erupted. Farther to the east, material later to become the lower part of the Three Rivers schist was deposited contemporaneously. Tuffs, clay-shale, and abundant limestones constituted the principal rocks, but minor amounts of volcanic rocks and cherts were also present. The assemblage representative of the Three Rivers schist succeeded the Homer quartzite farther west. The Three Rivers schist overlies the Homer quartzite along the East Branch of Dry Creek.

Since the age of these marine rocks is unknown, and neither the bottom nor the top of the section is present, the former presence and possible thickness of still younger sediments must remain in doubt.

In the Upper Jurassic, the thick section of sediments comprising the geosyncline out of which the ancestral Sierra Nevada arose, was compressed and tightly folded. The Kaweah series was thereby deformed and recrystallized under stress and increased temperature.

The intrusion of batholithic bodies of plutonic rock followed the completion of the processes of folding, and contact metamorphism occurred at that time as a result of the heat from the magma bodies. Not all of the contact metamorphism was synchronous, for it is clear that the several bodies of magma rose and consolidated serially.

The orogenic episode terminated with the crystallization of the plutonic rocks. No younger rocks other than recent stream gravels are known in this area. Presumably the southern Sierra Nevada has been subject to erosion during the greater part of time since the growth of the ancestral range in the late Jurassic. This long-continued erosion exposed plutonic rocks over the greater part of the area herein described. Only the lowest portion of the once-continuous cover of metamorphosed sediments and volcanic rocks now remains, and even the floors of these roof pendants are exposed in many places. It is along the lower walls, and particularly along the floors, of the roof pendants that the contact metamorphism is most strongly developed. Such regions, where limestones are present, are most likely to contain minerals of economic importance.

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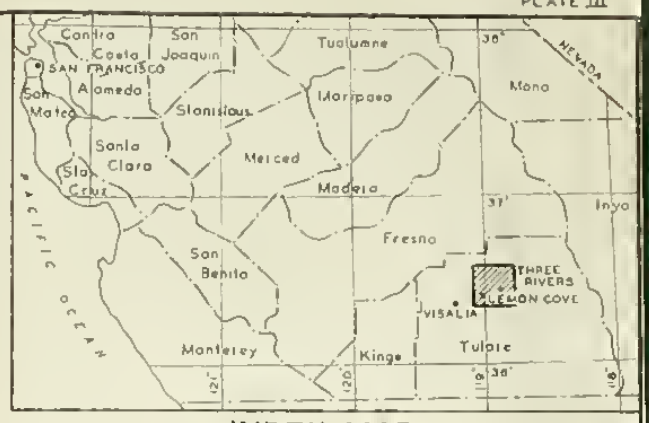
PLATE III



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13. Tulare County Tungsten Mines
14. Baty
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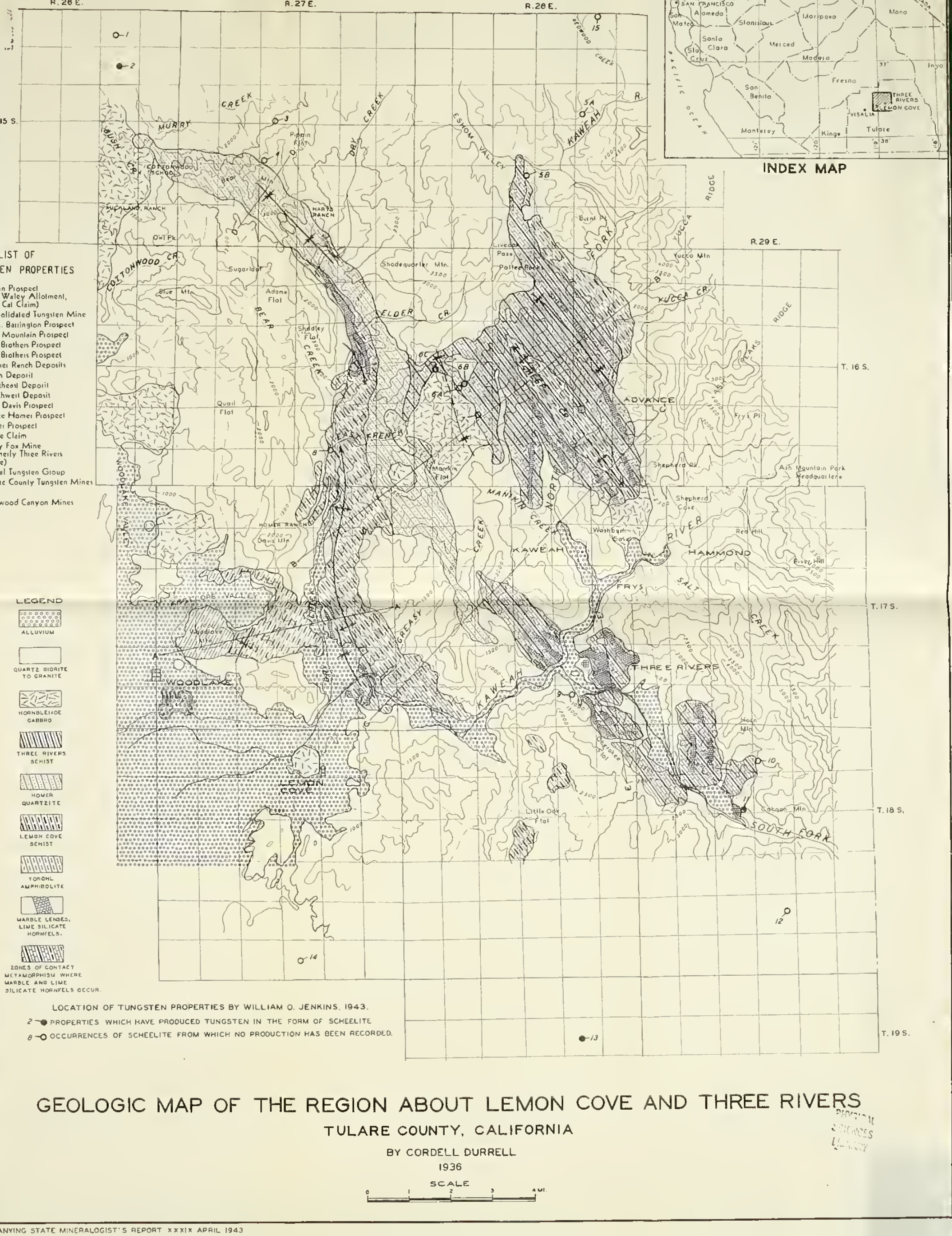

LEGEND

- ALLUVIUM
- QUARTZ DIORITE TO GRANITE
- HORNBLENDE GABBRO
- THREE RIVERS SCHIST
- HOMER QUARTZITE
- LEMON COVE SCHIST
- YOKOHL AMPHIBOLITE
- MARBLE LENSES, LIME SILICATE HORNFELS.
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GEOLOGIC MAP OF THE REGION ABOUT LEMON COVE AND THREE RIVERS

TULARE COUNTY, CALIFORNIA

BY CORDELL DURRELL

1936

SCALE

0 1 2 3 4 MI.

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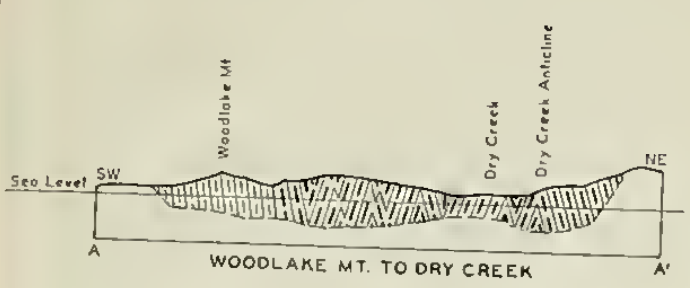
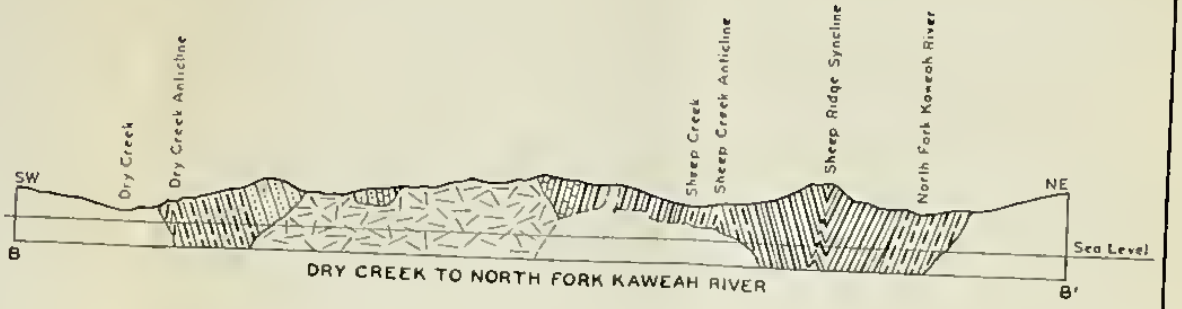
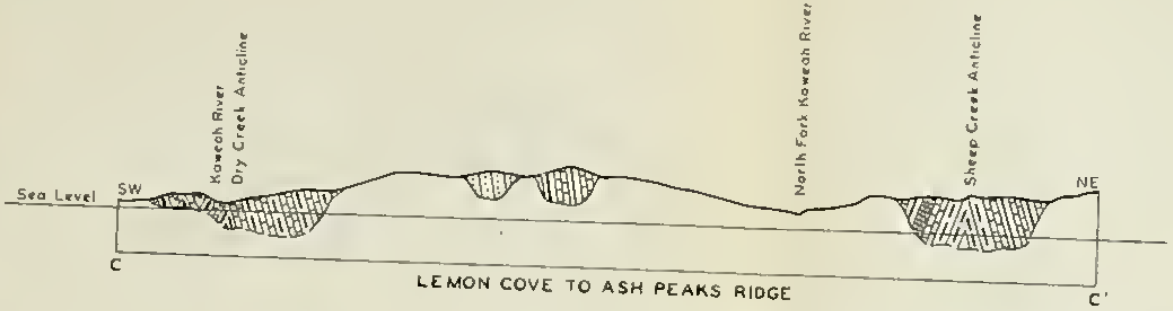
PLATE IIIA



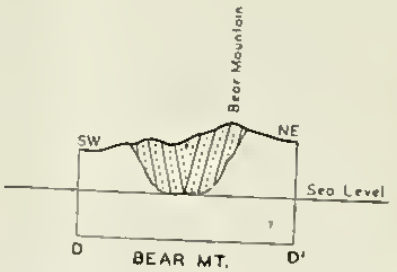
WOODLAKE MT. TO DRY CREEK



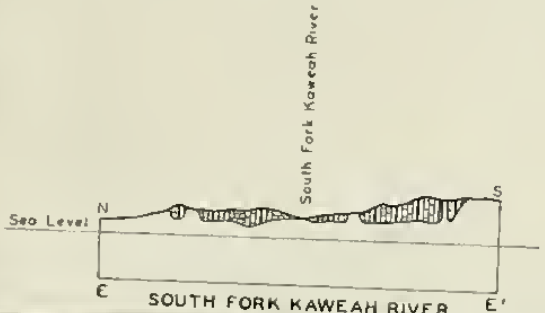
DRY CREEK TO NORTH FORK KAWEAH RIVER



LEMON COVE TO ASH PEAKS RIDGE



BEAR MT.



SOUTH FORK KAWEAH RIVER

GEOLOGIC CROSS SECTIONS

SOUTHERN SIERRA NEVADA NORTHEAST OF VISALIA

CORDELL DURRELL 1936

SCALE
0 1 2 3 4MI
HORIZONTAL & VERTICAL

LEGEND

- QUARTZ DIORITE TO GRANITE
- HORNBLENDE GABBRO.
- THREE RIVERS SCHIST
- HOMER QUARTZITE
- LEMON COVE SCHIST
- YOKOHL AMPHIBOLITE
- MARBLE LENSES, LIME SILICATE HORNFELS.
- ZONES OF CONTACT METAMORPHISM WHERE MARBLE & LIME SILICATE HORNFELS OCCUR.

ACCOMPANYING GEOLOGIC MAP (TOPOGRAPHY AND BASE AFTER U.S.GEOLOGICAL SURVEY, DINUBA, LEMON COVE, TEHIPITE AND KAWEAH QUADRANGLES.)

ACCOMPANYING STATE MINERALOGIST'S REPORT XXXIX, APRIL 1943

TUNGSTEN DEPOSITS NORTHEAST OF VISALIA, CALIFORNIA*

By William O. Jenkins

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INTRODUCTION

The tungsten deposits northeast of Visalia, California, are part of elt of deposits that extends from the Havilah and Kern River region Kern County, through Tulare and Fresno counties, to the northwestern rt of Madera County. Scattered deposits of tungsten ore are found Mariposa and Tuolumne counties and as far north as Grass Valley d Portola.

Most of these deposits are small, although a few have proved themves quite substantial producers and some others give promise of conlerable ultimate tonnage. The ore in a few is high-grade, as the nsolidated Tungsten mine in Tulare County, where "spuds" of sorted e have been sold as high-grade concentrates without treatment other an crushing. However, this is most unusual, and the ore in the average rkable deposit contains somewhere between ½ and 1 per cent tungsten ioxide.

Most of the discoveries have been made within the past 2 or 3 ars; before that time, the presence of tungsten ore was virtually known over much of this region. Hence, it is to be expected that more scoveries will be made during this year and for as long afterward as e demand for tungsten stimulates the search for ore deposits.

Until recently the problems of concentration and marketing of ore ve prevented the development of some of the smaller deposits. There s been no local market for the ore itself, custom concentrating plants e few and far between, and in most cases the small deposit does not stify construction of a mill. Hence many have remained idle.

* This report has been prepared to supplement the preceding paper by Cordell rrell, *Geology of the Sierra Nevada Northeast of Visalia, Tulare County, California.* cations of the tungsten deposits described have been plotted on the geologic map companying Durrell's report.

Manuscript submitted for publication June 8, 1943.

However, recently (April 1943) Metals Reserve Company has esta lished an ore purchase depot in Fresno, where ore in small lots is pu chased from the mines. Already this has resulted in renewed activi of some of the small mine operators, who are hauling their ore to Fresn

Mining operations in the area northeast of Visalia should be co siderably stimulated, for the ore purchase depot is within economic hauling distance of this area.

GEOLOGY OF THE DEPOSITS

All occurrences of tungsten in this area are found in contact-met morphic zones. The ore mineral, scheelite ($CaWO_4$) is present in tacti which has been formed by the alteration and replacement of limesto adjacent to granitic intrusions. The tactite is made up chiefly of garn epidote, and quartz, and minor amounts of calcite and other minera The scheelite and quartz are generally associated with each other a appear to have been introduced into the matrix of garnet and epido

Where thick lenses of limestone have been replaced with tactite on along their borders, adjacent to the granitic contacts, it may be shov that the formation of tactite has taken place along bedding planes, joi planes, and fractures. Where such openings have not existed, the lim stone is affected only by a complete recrystallization, the end product these cases being a white, or gray and white, banded, usually coars grained marble.

Small limestone lenses along the contacts of roof pendants and sma isolated pendants composed wholly of limestone are often complete replaced with the tactite minerals.

Distribution of scheelite is characteristically very erratic, althou in some cases it has been evenly disseminated throughout small layers tactite. Scheelite may be deposited along relict bedding planes, joi planes, or in any fractures or brecciated areas or other openings th existed in the mass at the time of introduction of mineralizing sol tions. There are very few cases where scheelite has been deposited the granite itself, in the marble, or in adjacent schistose rocks, and ev where such occurrences have been noted, the mineralization is extreme limited in extent.

In general, the formation of tactite is limited to granite-limesto contacts, whether the limestone be a part of a large pendant or a be of metamorphic rocks, or a small, isolated pendant completely surround by granitic rock; or whether the granitic rock be a part of the ma granitic intrusion or a relatively narrow dike or apophyse.

Field observations in this and other areas indicate that in ma cases, scheelite mineralization is more closely related to undifferentiat border dikes, satellitic dikes, and pegmatites than to the main intrusi mass itself.

PROSPECTING FOR SCHEELITE

The area northeast of Visalia has so far been incompletely pro pected. Few prospectors are or have been active in this area, althou some tungsten deposits have been discovered here within the past 2 3 years. Prospecting is easier here than in many areas, for most the region is quite readily accessible and the climate is such that wo

n be carried on at any time of year. The chief criteria, the limestone-anite contact and the tactite outcrop, are easily recognized. Soil ver is in general thin and outcrops are plentiful.

First, one should not lose sight of the fact that the presence of tactite es not necessarily mean the presence of scheelite in any quantity. though many of the garnet-studded outcrops are rich in scheelite, ners are barren, or nearly so. They must be examined carefully with e ultra-violet lamp before positive assurance may be had of the presence scheelite ore.

Prospecting should be carried on in a systematic manner. The geo-gic map should be consulted and a likely area chosen. One should go er this area thoroughly, following the limestone contacts and investi-ting carefully any occurrences of tactite either as float or in place. large black cloth may be carried to serve as a darkroom under which observe the suspected rocks. A piece of black sateen is very satisfactory r this purpose. It is fairly light-proof and has the added advantages being both inexpensive and light in weight. It should be at least eet square.

The location of any occurrence of scheelite ore should be carefully rked and returned to at night for further investigation with the ultra-olet lamp, for it is only at night that a thorough examination with this strument can be made satisfactorily. During the daylight hours, even nen a black cloth is used, it is very easy to miss the best part of a show-g, for the field of view is limited to a small area under the cloth.

There are several makes and models of ultra-violet lamps on the rket that are quite satisfactory for prospecting. Too much weight is be avoided, but weight should not be eliminated at the expense of iciency. Prospecting is hard work at best and its results should not jeopardized by the use of an inefficient lamp.

The value of the pick and shovel must not be overlooked. The posit may be covered with rock and soil overburden and its position dicated only by the presence of tactite float on the hill slope below. few hours of digging may uncover a good showing of tungsten ore in ace. Even where the tactite is exposed in an outcrop, its width and ngth may be extended considerably by the judicious use of the pick d shovel.

It is always wise, and generally more economical in the long run check field estimates of grade of ore against assays. One or more mples which under the ultra-violet lamp look representative of the posit should be taken to a competent assayer for determination of ngsten trioxide content. If a yellow fluorescence is displayed, deter-nation of molybdenum content in concentrates should also be made. is unwise to rely entirely upon the lamp for estimating grade. No o deposits are alike and although the prospector may become accus-ned to estimating ore grade in one deposit with the lamp, he may find s estimates either too high or too low when examining ore from another posit. After a few check assays have been made, it is much easier to imate the tenor of ore with the lamp alone.

After the presence of an ore deposit has been established, it is tural to begin to think in terms of possible tonnage. Estimating ton-ge of ore in these deposits, even where exposures are good, is a hazard-s undertaking. The erratic shape of the typical tactite body, its

characteristic lack of continuity and lenticular nature inherited fr the limestone body, together with the usual hit-or-miss distribution scheelite, make accurate estimates impossible. But since this difficu presents itself throughout the life of the mine, and since some sort estimate must be made, some method of tonnage estimating must be us

It is unwise to project ore very far beyond visible limits, or assume that all the tactite is ore. A careful examination of the o crop with an ultra-violet lamp will give some idea of the distribution scheelite within the tactite and from this a tentative percentage fac may be arrived at which can be applied to the overall tonnage estima converting tactite tonnage to ore tonnage.

The figure of 12 cubic feet of ore in place to the ton is genera safe to use, although some ore is somewhat heavier than this.

DESCRIPTION OF DEPOSITS

General Discussion

Following is a list of tungsten deposits situated in the area nor east of Visalia, together with descriptions of the individual depos These are numbered and the locations and numbers have been plot on the geologic map by Durrell, which precedes this article. A stu of this map will demonstrate the relationship between distribution the deposits and marble-granite contact areas.

No such list as this may be considered to be in any sense compl Undoubtedly deposits have been discovered which have not been repor to the writer and hence do not appear here. It is hoped that even the list is complete as of the date of its compilation, it will not l remain so, and that many more discoveries will be made in this ar

[1](1) Indian Prospect (Bill Waley Allotment, Tom Cat Claim)[2]

Location: W½ sec. 2, T. 15 S., R. 26 E., Tulare County, on no side of Drum Valley, elevation 2000 feet, about a mile north of Har Hill mine, Dinuba quadrangle.

Several prospect holes have been sunk here in past years, presu ably in search of minerals other than scheelite. One open cut 25 f long, dug at an undetermined date, exposes the tungsten ore.

The property was located as the Tom Cat mining claim in Nov ber 1941. However, since this property is part of an Indian allotm the claim was invalid. Property was leased early in 1943 by the Ind Service to Strickland and Appleby, Exeter, who turned it over to present operators, Tyler Jack, Glen Henry and William Bloyd, Reedley.

Rather fine-grained scheelite occurs disseminated in tactite as ciated with coarse-grained white marble over a 3- to 5-foot width approximately 150 feet along a granite contact which parallels the str of bedding in the marble. The granite along the contact is decompo and very friable. The contact strikes N. 75° W., dipping steeply the north at the open cut, but flattening to the west, toward the end the deposit, where the deposit is quite shallow and the granite pas under it close to the surface.

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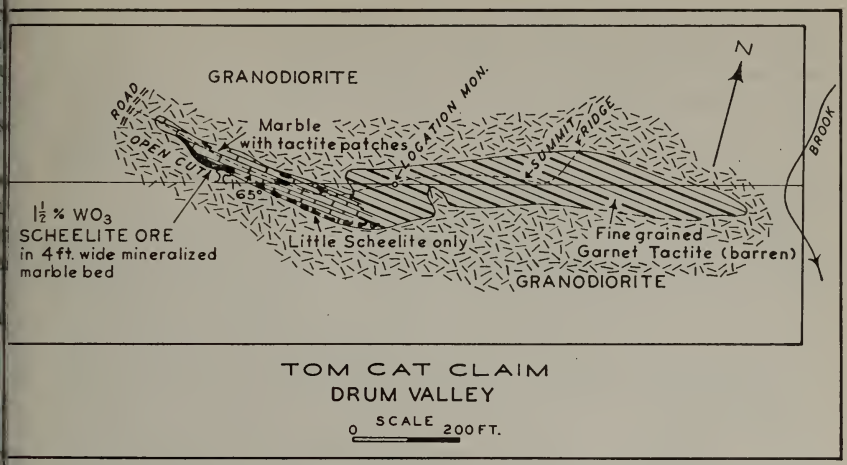
[1] For graphic location of this property and those properties described below, geologic map by Durrell in preceding report.

[2] Description of this property is by William O. Jenkins and James M. Little.



IG. 1. Geologic map of the Indian prospect (Tom Cat claim), Drum Valley, W½ Sec. 2, T. 15 S., R. 26 E., M.D., Tulare County. *Map prepared by James M. Little and William O. Jenkins.*

This deposit occurs at the southwest end of a ridge whose crest, hroughout its 700-foot length, is composed of tactite, which in the entral and eastern end is light in color, very dense and siliceous, con- aining no scheelite for the most part, although here and there scattered olors may be observed with the ultra-violet lamp. On the western end f the ridge, however, one finds the typical coarser-grained tactite char- cteristic of this area, which contains garnet, epidote, and calcite crys- als, many of them abnormally large (epidote crystals up to 4 inches ng have been observed). A fairly large amount of fine-grained quartz s present, appearing to have been largely introduced with the scheelite, hich is disseminated in the tactite as small crystals. The outcrop as whole is in contact on all sides with granitic rocks and may be con- idered as a small isolated pendant which has been subjected throughout o strong contact-metamorphic action.

The ore zone is rather porous, containing localized leached zones oth in the tactite itself and in the adjoining beds of marble. The tac- ite is fairly friable, but this is probably due largely to the influence f weathering. Distribution of the contained scheelite was controlled rimarily by the position of the granite contact and by the strike of edding in the marble, while minor cross-fractures and jointing appear o have exercised a secondary control.

At present (June 2, 1943) the operators have started stripping the lecomposed footwall granite from the deposit preparatory to mining he exposed ore and further developing the deposit. Development ore vill be milled locally or hauled to the Fresno ore-purchase depot of Metals Reserve Company, a distance of approximately 60 miles.

2) Consolidated Tungsten Mine (Harrell Hill Mine, Dinuba Mines)

Location: sec. 11, T. 15 S., R. 26 E., M. D., Tulare County, on the outheast end of Drum Valley, Dinuba quadrangle. Elevation 2000 feet.

The mine is located on Harrell Brothers ranch land. It was located nd leased in 1941 by the Parlier Prospecting Association, who built a

road to the outcrops and did some preliminary open cut work, subse quently (February 1942) leasing the property to Bruce McDonnell o Sacramento. A mill was erected on Slick Rock Creek at a distance o about 3 miles from the mine property and ore has been treated an concentrates produced since that time. In the spring of 1943 the prop erty changed hands and is now operated by Consolidated Tungsten. A present (June 1943) the mill is being operated 12 to 16 hours daily an is treating an average of about 35 tons of ore daily.

The deposit consists essentially of a small marbleized limeston pendant in granite, which has been strongly sheared and in which muc of the marble has been replaced by tactite, replacement having take place along bedding planes in the marble and along strong cross-fracture and sheared zones in the pendant. Bedding in the marble strikes N 50° E., dipping vertically. Scheelite mineralization has been very stron in the upper part of the deposit and is accompanied by quantities o quartz. In the eastern part of the pendant a massive outcrop of quart may be observed at the surface and although this has not yet been encoun tered in the underground workings, present evidence indicates its rol as a "feeder" for the high-grade ore shoots in the mine.

At present the orebody has been developed for a maximum distanc of over 200 feet along the strike and to a maximum width of approxi mately 50 feet. The shape of the orebody cannot be known at present however, for the ore has been distributed irregularly along the opening in the mass. A maximum depth of ore of 75 feet has been prover although the ore in the lower level is neither as wide nor as rich as tha nearer the surface. Development has been accomplished with latera openings which follow the ore zones, and with raises. Stopes are timbere with square sets.

Much very high-grade ore has been recovered during the past yea from the main ore shoot in the upper level. Many tons of high-grad concentrates have been produced solely by hand sorting in the min

Some of the scheelite is fine-grained and disseminated in the tactit but most of the values have been in extremely coarse-grained scheelit crystals occurring in the fractured zones.

(3) J. A. Barrington Prospect

Location: sec. 16, T. 15 S., R. 27 E., 2 miles southwest of Badge Tulare County, Dinuba quadrangle.

A considerable amount of prospecting and preliminary developmen work has been done here by J. A. Barrington during the winter an spring of 1943. Work done to date indicates that the deposit consist of two or more small pods of tactite, completely surrounded by graniti rocks. The maximum length of the largest indicated pod is 50 by 7 feet. The tactite in the surface outcrops and in the open cuts is strongl weathered and contains scheelite distributed along joint planes an fractures and locally disseminated in the tactite adjacent to the igneou contact.

The deposit appears to be the shallow remnant of a limestone pe dant, although greater depth and lateral extent may be proved b further development work.

4) Bear Mountain Prospect

It is reported that operators are going to begin development work n a prospect situated on Bear Mountain, T. 15 S., R. 27 E., east of uckland Ranch, Dinuba quadrangle. No investigation has been made f the deposit and no further information is available at present. Loca- on uncertain.

5A, 5B) Hill Brothers Prospects

(*No. 5A*). Location: sec. 14, T. 15 S., R. 28 E., on the northwest ank of the North Fork of the Kaweah River, 3¼ miles east of Eshom alley School, Tulare County, Tehipite quadrangle. Elevation 3500 feet.

This claim was located by Ed Hill, his brothers and an associate, ho live in Eshom Valley. No work has been done to date on the claim xcept prospecting and location work.

Fine-grained, dark-colored tactite has been formed along the contact f marble and granite. Scheelite, accompanied by some powellite, is isseminated throughout the tactite in small crystals. The bedding in he marble strikes east, standing in a near-vertical position.

On the south side of the deposit, this contact parallels the bedding n the marble, while on the eastern end, a granite embayment cuts off the ens. The richest ore is to be found along this eastern end. Apparently he mineralizing solutions were allowed easier access to the limestone here the truncated ends of the beds were exposed than they were where he contact follows the bedding planes. This condition has been observed lsewhere, as well.

An aggregate total length of ore of perhaps 75 feet, together with n average width of 4 feet is indicated in the outcrops, whose vertical ange of distribution on the steep canyon walls is more than 50 feet.

(*No. 5B*). Location: sec. 28, T. 15 S., R. 28 E., 2 miles southwest f No. 1, above, on the south slope of Eshom Creek Canyon. Elevation 000 feet.

This claim was located by Ed Hill, his brothers and an associate, of Eshom Valley.

This deposit has also been formed along a granite-limestone contact t the northeastern end of a long and broad belt of metamorphic rocks which widens to the south and extends as far as the Kaweah River at Washburn Cove. The tactite is in general coarse-grained and is much veathered. It is largely covered by a mantle of surface soil, the only good exposures being in a crosscut trench which the owners have dug cross the outcrop. Little can be said of the extent of the deposit at this writing. However, a width of 10 feet and a length of 40 to 50 feet is ot unlikely for the tactite.

6A, 6B, 6C) Homer Ranch Deposits

The Homer Ranch deposits comprise three separate deposits, all situated on patented agricultural land owned by the Homer family, Lemon Cove, California. A considerable amount of exploration work was carried on here during the fall and winter of 1942, especially on the "Main deposit," by H. W. Thorne, Pasadena, California. At present, he property is idle (June 1943).

No. 6A—Main Deposit. Location: sec. 20, T. 16 S., R. 28 E., Tulare County, Tehipite quadrangle. Elevation 3000 feet.

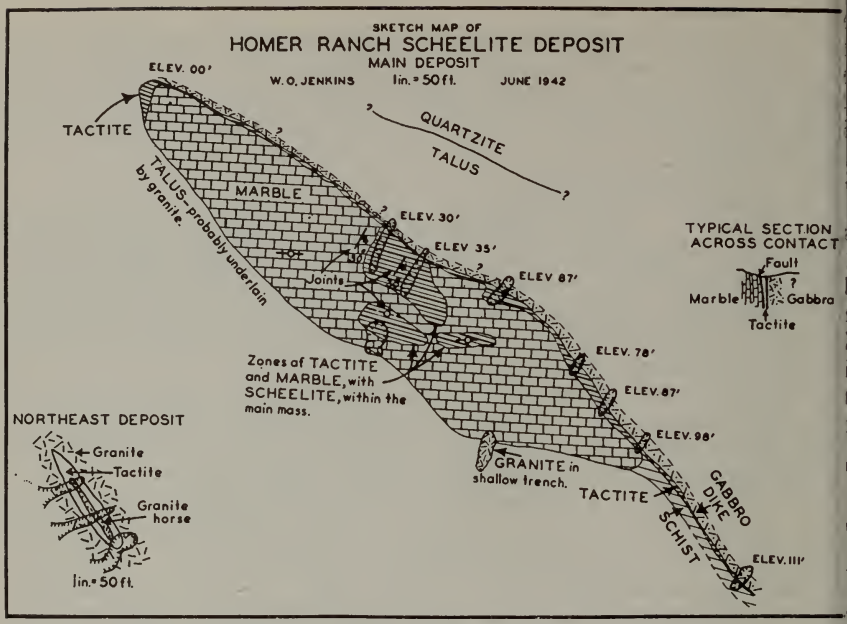


FIG. 2. Sketch map of the Homer Ranch scheelite deposits.

The scheelite-bearing tactite of the main deposit occurs along th border and within the main mass of a well-defined lens of marble Roughly lenticular in shape, this lens has a length of 400 feet and a average width of approximately 50 feet. Its direction of elongation i N. 65° W. Bedding, which is well-preserved in the granular, whit marble, strikes east and dips vertically.

The southwest side of the marble body is in contact with decomposed granite. Little or no tactite has been formed along this contact and ther are no known occurrences of scheelite immediately adjacent to it.

Along its northeastern side, the marble is in contact with a dik of hornblende gabbro. Trenching and stripping of overburden ha shown the presence of this rock for the full length of the lens. Alon the contact, a narrow zone of gouge and breccia indicates movement A zone of tactite is present along the full length of this contact. It varie in width from 6 inches to 8 feet and carries medium-grade scheelite or through most of its extent.

At least three occurrences of scheelite-bearing tactite of irregula outline occur within the main mass of the marble lens. Their distribu tion is controlled by jointing and bedding in the marbleized limestone Some very high-grade ore has been found in these zones.

No. 6B—Northeast Deposit. Location: sec. 20, T. 16 S., R. 28 E. Tulare County.

Situated $\frac{1}{4}$-mile northeast of the main deposit, this deposit consist of a pod of tactite 70 feet long, whose average width is 10 feet. Thi pod is surrounded by granite and is apparently very limited in size Ore is in general low-grade.

No. 6C—Northwest Deposit. Location: sec. 19, T. 16 S., R. 28 E. Tulare County. One mile northwest of the main deposit, tactite i

exposed intermittently over a distance of several hundred feet. Some of this material shows scheelite with the ultra-violet lamp. It is associated with a lens of marble and is adjacent or close to the contact of a large intrusion of hornblende gabbro. Practically no work has been done here to expose the ore.

7) Tom Davis Prospect

Location: one mile southeast of main Homer Ranch deposit, in sec. 29, T. 16 S., R. 28 E. Owned by Tom Davis, Woodlake, California.

This deposit is said to be similar to the main deposit of the Homer Ranch. It is situated along the contact of a large body of gabbro and marbleized limestone. The marble lens is 1000 feet long overall and 100 feet wide. Tactite occurs along the gabbro contact and is distributed irregularly in the marble. It is reported that the ultra-violet light shows the presence of a considerable amount of scheelite. No work has been done here.

8) Alice Homer Prospect

Location: sec. 34, T. 16 S., R. 27 E., on Dry Creek, 8 miles north of Lemon Cove. Owned by Alice Homer, Lemon Cove, California.

A small pod of tactite outcrops here along the contact of a broad belt of metamorphic rocks and granite. The tactite is dense and hard and is a dark-green color. Scheelite is fine-grained and disseminated in the tactite. Exposures are very poor.

A little exploration work was carried on here during the summer of 1942, but there has been no work done since.

9) Carter Prospect

Location: sec. 35, T. 17 S., R. 28 E., 1 mile southwest of Three Rivers. Owned by Mrs. Carter, Three Rivers.

At the time this prospect was examined, surface work had exposed a few feet of tactite ore in contact with granite. No indications of possible size were given by this work, although the deposit appeared to be another of the small remnants which are to be found scattered through this region. A few tons of ore are said to have been milled from this prospect.

10) Eagle Claim

Location: sec. 3, T. 18 S., R. 29 E., on the south side of the North Fork of Cinnamon Creek, on Bald Hill, Tulare County, Kaweah quadrangle. Elevation 3000 feet.

This claim was located in December 1942 by Robert Records and Artie Helm, Woodlake. Preliminary prospecting work and location work was done by these men. The claim has now been sold to J. Spitler, C. Tibbals, and F. Adams, Dinuba, and these men are reported to be doing further work to develop the ore.

The deposit is situated on the northeast side of a mile-wide area of metamorphic rocks, along the contact of marble and granite. Several occurrences of tungsten ore have been noted on the mining claim. Scheelite is present in tactite which has been formed adjacent to the granite contact. It is irregularly distributed along sheared zones, bedding, and jointing in the marble. Little work has been done to date, although geological conditions favor the possibility of a deposit of considerable size.

(11) Grey Fox Mine (Formerly Three Rivers Mine)

Location: sec. 16, T. 18 S., R. 29 E., on the west slope of Cahoon Mountain, Tulare County, Kaweah quadrangle.

This property is owned by H. E. Root and Rose Belle Root, who have leased it to William Clinesmith and a partner. Two tunnels have been driven on the property during the past 2 years, by former leasers. Both have exposed some ore. The present leasers have opened up a face of ore 3½ feet wide and 10 feet high. A sample taken across this face assayed 1.05 percent WO_3.

The ore deposit is located on the eastern border of a quarter-mile-long lens of marble, where it is in contact with granite. The strike of the contact roughly parallels that of the bedding in the marble, being N. 15° W., dip vertical. Development work to date indicates that the ore is limited to the immediate contact zone, in a zone 3 to 4 feet wide. However, it is possible that a deposit of considerable width may be developed here, for at intervals along its strike the marble is cut by strong shear zones following cross-fractures, or cross-jointing, which are approximately normal to the granite contact. From observations made elsewhere, it has been noted that this condition is often accompanied by the formation of tactite bodies in the marble for some distance from the igneous contact. The length of the deposit along the strike has not yet been determined, and lack of good exposures makes it impossible to ascertain.

Work is being carried on here at the present writing (June 2, 1943). Eighteen tons of ore have been treated at a local custom mill.

(12) Royal Tungsten Group

Location: sec. 26, T. 18 S., R. 29 E., on west side of Grouse Peak, Tulare County, Kaweah quadrangle. Elevation 5000 feet.

Claims were located in the spring of 1941. They are owned by George W. Hicks and son, John C. Brockman, et al. Work done to date consists of a few small open cuts and one 20-foot pit.

Here an unusually large mass of tactite has been formed along the granite contact of a broad belt of marbleized limestone. The tactite outcrop is very prominent for at least 700 feet along the brow of Grouse Peak, forming a steep bluff. Its average width is 50 feet. The strike of this mass is east, while its dip is quite moderate, being 25° N. Another body of tactite outcrops a few hundred feet to the north; this may or may not be part of the same deposit. In some parts of the mass the tactite is less well developed than in others and grades into areas of impure crystalline limestone.

In spite of the great size of this tactite body, very little scheelite can be seen with the ultra-violet lamp, and this only in localized areas. This is a very interesting condition, for it demonstrates that the factors necessary for the formation of a body of tactite are not identical with those responsible for the introduction of scheelite into that mass, and emphasizes the absolute necessity for thorough prospecting with the ultra-violet lamp after the tactite itself has been discovered.

In the spring of 1943, no more work had been done here, although the owners signified their intention of exploring the deposit further.

(13) Tulare County Tungsten Mines

Location: sec. 11, T. 19 S., R. 28 E., on Will Gill Ranch property, 14 miles east of Lindsay. The mine is in Tulare County, Kaweah quadrangle. Elevation 2300 feet.

This mine property is owned by the Will Gill Ranch and is leased to Tulare County Tungsten Mines, who have been mining and milling here since early 1942. A very substantial tonnage of medium-grade ore has been developed and the milling capacity has been increased to about 100 tons per day.

The deposit is contact metamorphic and the scheelite, in general rather fine-grained, is disseminated in tactite. The tactite bodies lie between granite and a fairly broad belt of metamorphic rocks—schist and crystalline limestone—which have a nearly vertical attitude and strike in general N. 15° W., although there is considerable local deviation from this course.

Mineralization appears to be strongest adjacent to the granite, although formation of tactite and deposition of scheelite have taken place for a distance of some 50 feet from the contact. Within this zone, schist layers are present, indicating a pre-mineral condition of alternating beds of schist and limestone. A rather intensely sheared zone adjacent to the granite contact has resulted in a porous mass which has allowed mineralization to take place over a wider zone than may be considered usual for this region.

Mining is being carried on by open-cut methods and ore is hauled by truck to the company's mill, 1½ miles distant.

(14) Baty Mine

Location: sec. 34, T. 18 S., R. 27 E., about 1½ miles southeast of Lind Cove. Elevation 700 feet.

Property is owned by Wm. Meherten and leased by S. P. Baty, Exeter. The deposit has been developed by one 15-foot shaft and an open cut 40 feet long.

Moderately dipping beds of marbleized limestone are faulted against steep-dipping mica schist, producing a porus zone which is cut off by a granite embayment. Coarsely crystalline scheelite is associated with a strong quartz mineralization near the granite contact. The mineralized zone extends along the marble-schist fault contact for at least 60 feet from the granite, and indications are that mineralization continues for some distance back into the marble, along the bedding planes and adjacent to the granite contact where it truncates the marble lens. Light-colored tactite has been formed throughout the mineralized zone.

Mr. Baty has already shipped a small amount of ore and is operating the property at present (June 2, 1943). He will probably haul ore to the Metals Reserve Company ore-purchase depot in Fresno.

(15) Redwood Canyon Mines

Location: sec. 2, T. 15 S., R. 28 E., in Redwood Canyon, Tulare County. Elevation 5250 feet.

The group of claims now known collectively as Redwood Canyon mines, is owned by Edith F. Barton, et al., Badger, California. It has been leased to M. C. Richardson and Edward Homer, both of Lemon Cove, California. These men have started development of a tungsten orebody

recently found on the Lamb Mine claim, at the northwest end of the Redwood Canyon group. Preliminary sampling and development work have shown the presence of high-grade scheelite ore in an orebody of undetermined size.

The Lamb Mine claim is located along the strike of one or two or more roof pendants of calcareous metamorphic rocks, in granitic intrusives. The pendants parallel each other and may be traced by means of discontinuous exposures for a distance along the strike of more than a mile. At several points along these pendants, mineralization has occurred and ores of tungsten, copper, and some silver and gold have been found.

The strike of bedding in the roof pendants is N. 35° W. and the dip from 55° to 80° SW. It has been impossible, because of poor exposures, to determine thickness and continuity of the metamorphics. A heavy covering of detrital material is general in this rather heavily forested area.

In the vicinity of the Lamb shaft, open cutting has exposed a 45-foot thickness of tactite. However, the full width is not known, for the contacts have not been exposed. Near the center of this exposure is a mineralized bed of tactite, apparently occupying a shear zone in the garnetiferous rock. The zone is from 5 to 6 feet thick and is well exposed in the uppermost 15 feet of the shaft.

For a distance of about 12 feet below the surface, the ore zone is thoroughly leached and very porous. Secondary calcite has been deposited in the openings. Little scheelite is to be found in this zone. However, in the shaft, at a point 12 feet below the original surface, high-grade scheelite ore occurs in the tactite.

There is evidence of secondary deposition of scheelite at the bottom of the leached zone in the friable, decomposed tactite. Whether this is deposition by chemical or mechanical means is not known, but it seems logical to assume it to be mechanical, at least in part. The scheelite, which is very fine-grained and disseminated uniformly in the tactite, could not have remained in suspension on the porous, leached upper part of the orebody after the soluble material in the gangue was removed by solution, and could readily have migrated downward mechanically until arrested by the dense primary tactite ore. The nature of deposition suggests strongly that such a process has taken place.

Scheelite in the primary ore below the leached zone is in general very fine-grained. Its distribution on the tactite is remarkably uniform. The exposed ore is high-grade, assaying from 3 to 10 percent WO_3. Gangue minerals are calcite, quartz, epidote, and garnet. The ore is very hard and dense and contains small amounts of iron and copper sulphides.

Under the ultra-violet lamp, most of the scheelite fluoresces with a golden color, presumably because of the presence of some powellite, which is known to occur with the scheelite here to some extent.

The hanging wall of the ore zone is composed of dense, brown tactite, containing a predominance of garnet. There is a 30-foot width of this, at least, as exposed in the open cut. For the most part, this zone is barren of scheelite. It is thick-bedded to massive and has the same dip and strike as the ore zone.

Footwall material is iron-stained, decomposed, soft tactite, containing some scheelite adjacent to the ore zone, but barren a few feet away

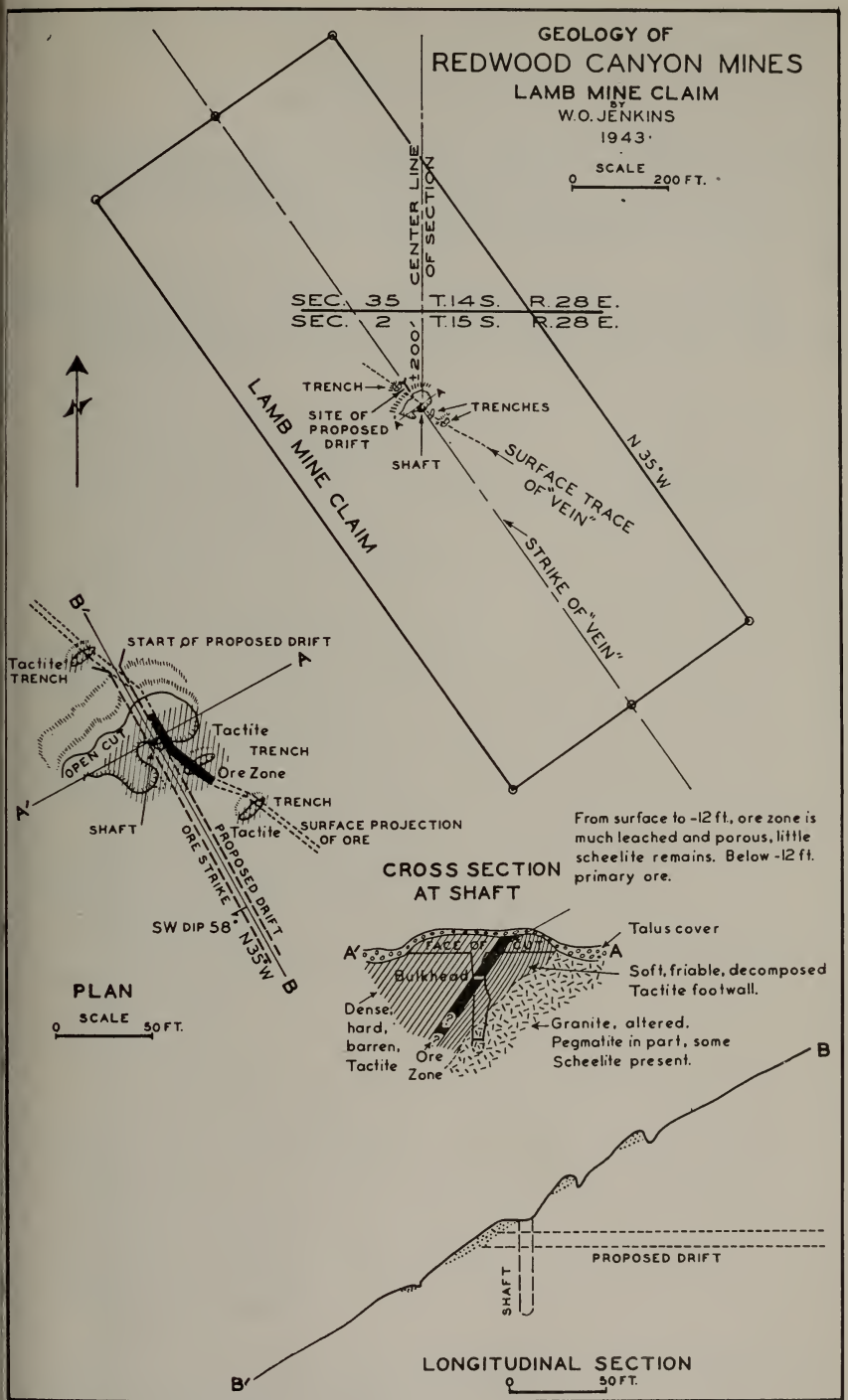


FIG. 3. Geology of Redwood Canyon Mines, Lamb Mine claim.

from it. It is in turn in contact with granite, which is exposed in th bottom part of the shaft. In the shaft, the footwall zone between granit and ore is about 12 feet thick; at the surface the distance is in excess o 15 feet, but lack of exposures prohibits its determination.

A small amount of scheelite may be found in the footwall tactit where it is exposed in the shaft, and some is even present in the granit at the shaft bottom. This granite is in part pegmatitic and is though to be a differentiate of the main mass and probably closely related t the deposition of scheelite in the adjacent rocks.

Other Deposits

There are two or three occurrences of tungsten ore 3 or 4 miles soutl of Lemon Cove, upon which a little exploration work has been done.

EOLOGY OF THE SAN BENITO QUADRANGLE, CALIFORNIA*

By Ivan F. Wilson

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* Thesis prepared in partial fulfillment of requirements for Ph.D degree, Department of Geological Sciences, University of California, Berkeley. Manuscript submitted for publication March 1943.

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ABSTRACT

The San Benito quadrangle, located 125 miles southeast of San Francisco, embraces parts of the Gabilan and Diablo Ranges of the central Coast Ranges of California. It includes a part of the Pinnacles National Monument, which lies mainly to the south; and is traversed by the San Andreas fault zone. The quadrangle is mapped on a scale of 1:62,500.

Topographically most of the region is in a stage of late youth or early maturity, but remnants of an older cycle of erosion which reached late maturity are preserved both in the Gabilan and Diablo Ranges. The steep southwestern front of the Diablo Range is characterized by large landslides. Five types of vegetation are distinguished, which show a decided geological influence in their distribution.

Some 36 cartographic units were mapped. These occur in three main stratigraphic provinces: (1) the Butts Ranch syncline, in the eastern part of the area; (2) the San Benito River area, a northwest-trending belt in the central part of the quadrangle; and (3) the Gabilan Range, to the southwest. In the first two provinces, located in the Diablo Range, Franciscan (Upper Jurassic) is the oldest rock exposed; in the Gabilan Range, Santa Lucia granite (pre-Franciscan) is the basement rock.

In the Diablo Range, Franciscan is overlain by undifferentiated Knoxville and Paskenta shales (Upper Jurassic and Lower Cretaceous); a considerable thickness of marine sandstone and shale in the Upper Cretaceous Panoche group, divided into four members; and a thin belt of the Upper Cretaceous Moreno shale. Four middle and upper Eocene formations are distinguished in the Butts Ranch syncline, and two middle Eocene formations are found in the Browns Valley area in the northwestern part of the quadrangle. The youngest beds in the Butts Ranch syncline belong to the middle Miocene Temblor group, divided into three members. These Eocene and middle Miocene formations are chiefly alternating marine sandstones and foraminiferal shales.

Miocene volcanics overlie the Santa Lucia granite in the Gabilan Range, and are particularly well developed in the Pinnacles National Monument and in the Willow Creek area. These consist of rhyolite flows and dikes, a few basic flows, and a great thickness of subaerial rhyolitic breccias, known as the Pinnacles formation, believed to have been formed by vulcanian eruptions. The volcanics are overlain by the upper Miocene Monterey group, divided into three members. The Monterey sediments record a fluctuating Miocene shoreline on the eastern edge of the Gabilan Range, in that marine diatomaceous shale interfingers with and grades into non-marine arkosic sandstone and conglomerate toward the west. The coarseness of the interbedded conglomerate indicates that conditions of clear, quiet water, usually postulated for the deposition of diatomaceous shale, were not present.

In the San Benito River area Franciscan is overlain by fossiliferous littoral deposits of the upper Miocene Santa Margarita formation and the Pliocene Etchegoin group. Fossils indicate the presence of all three Pliocene divisions of the Coalinga district—Jacalitos, Etchegoin (restricted), and San Joaquin; but these could not be separated lithologically. A series of red beds was distinguished at the base of the Etchegoin group.

Much of the area was blanketed by Plio-Pleistocene land-laid sediments—the San Benito gravels—deposited later than, and probably as a result of, the main period of deformation of the region (upper Pliocene).

Two separate Tertiary seaways connecting the San Joaquin Valley with the Coast are believed to have crossed the Diablo Range. The earlier seaway, during the Eocene and middle Miocene, ran eastward through the Butts Ranch syncline and Vallecitos to the San Joaquin Valley. The upper Miocene and Pliocene seaway was farther southwest, and ran southeastward along the San Benito River and Waltham Canyon to the Valley. The shift of position is thought to have been caused by pre-Pliocene folding of the Butts Ranch syncline.

The structure well illustrates the contrasting effects of deformation on a "thin-blanketed" area—the Gabilan Range—consisting of a granite basement with a comparatively thin sedimentary cover; and a "thick-blanketed" area—the Diablo Range—containing over 10,000 feet of foldable Franciscan sediments and an equal thickness of younger sediments. The rocks in the Gabilan Range have been deformed chiefly by faulting, and by gentle folding of the sediments; whereas those in the Diablo Range have undergone strong folding, overturning, and thrust-faulting. Several high-angle thrust faults are in the area; the most important of these is the San Benito fault, developed from a broken anticline, along which a belt of Etchegoin sediments half a mile wide has been overturned for a length of 12 miles. Several of the thrust faults show evidence of reversal of movement after deposition of the San Benito gravels (Plio-Pleistocene). The Bear Valley fault which separates the granite and Franciscan basements, shows evidence of three periods of activity, starting probably in the Eocene, including two reversals of movement. The major structural features other than the thrust faults are the Butts Ranch syncline, a broad steeply folded and faulted structure, and the Tres Pinos syncline, a wide synclinorium in the main Franciscan area in the northern part of the quadrangle.

The only active faults in the area are the San Andreas, and a parallel fault, the Paicines fault. Both show evidence of recent horizontal displacement, the southwest side of each having moved relatively northwest. The San Andreas fault, which appears to be of comparatively recent origin, in part developed along the line of weakness of the granite-Franciscan contact followed by the Bear Valley fault, but it developed a straighter course. The steeply dipping Bear Valley fault diverges as much as half a mile southwest of the San Andreas.

The structural history indicates not just one period of folding often attributed to the Pleistocene in other parts of the Coast Ranges but rather a series of deformations dating back at least to the Eocene, the strongest being that of the upper Pliocene. The deformations recognized are: (1) normal faulting along the Bear Valley fault uplifting the ancestral Gabilan Range, probably in the Eocene; (2) gentle folding of part of the Butts Ranch syncline area in the middle Eocene; (3) normal faulting in the Gabilan Range in the middle Miocene; (4) folding of the Butts Ranch syncline, probably between middle and upper Miocene, at least between middle Miocene and middle Pliocene; (5) the most important deformation—strong folding, overturning, and thrust-faulting in the upper Pliocene; (6) gentle folding and faulting, including reversals of movement along upper Pliocene thrust faults, in the late Pleistocene or Recent; and (7) recent horizontal displacement along the San Andreas and Paicines faults—the only deformation which is considered to be "active."

Economic deposits have not been greatly developed in the area. The principal deposits are quicksilver, occurring along faults mainly in Franciscan silica-carbonate rock and serpentine; and manganese ore, deposited as sedimentary lenses in Franciscan chert. A small amount of bentonite has been mined from Miocene vent tuff and a tuffaceous layer in the Pinnacles formation. Prospecting has been carried on for chromite, in Franciscan serpentine; gold, said to be an original constituent of Miocene rhyolite; copper, occurring in min

ralized zones in granite and in Franciscan sandstone; and coal, occurng as a thin impure, lignitic layer in the San Benito gravels. The l-bearing formations of the Coalinga and Kettleman Hills districts oss the quadrangle, but favorable structures for the accumulation of etroleum do not appear to be present.

INTRODUCTION

Despite the wealth of information regarding the California Coast anges that has accumulated under impetus of the search for oil, there e still many complicated areas in the highly folded heart of these nges which have scarcely been touched by the geologist. In recent ars, detailed studies of some of these regions—notably the Santa ucia Range—by Taliaferro and his students, have revealed that many our concepts of Coast Range structure and structural history, derived rgely from a study of the oil districts, must be revised. In particular ey suggest that the Coast Ranges have not undergone just the one riod of folding often attributed to the Pleistocene, but have been subcted to a series of deformations of greater or lesser importance dating ck at least as far as the Cretaceous. Because these deformations died t toward the basins and margins of the ranges, which are the mostudied portions, they have often been overlooked.

The San Benito quadrangle, covering parts of the Gabilan and iablo Ranges, is fortunately situated for a study of Coast Range ructural history and stratigraphy. Located midway between Monrey Bay and the Coalinga-Kettleman Hills oil districts, it was crossed y two separate seaways which connected the San Joaquin Valley with ie coast during the Eocene, Miocene, and Pliocene periods. Owing to re-Pliocene folding, the Pliocene seaway had a different course from iat of the earlier epochs. The stratigraphic succession in the quadngle is nearly as complete as in any other part of the Coast Ranges, id the stratigraphic and faunal details fill a gap between the betternown areas along the Coast and the San Joaquin Valley.

The structural complexity of the area is rendered interesting by ot one, but several periods of deformation. Of at least three epochs f folding represented, the latest (Pleistocene) was the least severe—ontrary to the condition found along the edge of the San Joaquin alley. Also of considerable interest is the discovery of reversals of ovement along some of the faults—including a close neighbor of the ell-known San Andreas fault, which traverses part of the area. The an Andreas fault itself—one of the two "active" faults in the region —appears to be of relatively recent origin.

The writer spent about 8 months in field mapping, during the mmers of 1938, 1939, and 1940, and at other intervals during these ears. The quadrangle is mapped by the U. S. Geological Survey on scale of 1:62,500, and covers 246 square miles. Aerial photographs ade for the Agricultural Adjustment Administration became available in the fall of 1939, and proved very useful in working out certain atures of the geology.

Several local geographic names have been added to the topographic ap and a few others changed in accordance with local usage to facilite discussion of the geological features. The misspelling of "Butts

Ranch'' on the map is pointed out, as this is an important place nam used in describing certain of the formations.

Fossil localities have been eliminated from the text to conserv space, but a list of localities may be consulted in the copies of th unpublished thesis obtainable at the University of California Librar at Berkeley.

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LOCATION AND GEOGRAPHIC FEATURES

The San Benito quadrangle is located in the central part of Sa Benito County, about 125 miles southeast of San Francisco. It includ parts of the Diablo and Gabilan Ranges of the central Coast Ranges California. The quadrangle contains no towns or settlements, but on scattered ranches. Hollister, the San Benito County seat, lies 25 mil to the northwest. The former settlement known as San Benito co tains only a post office and a few abandoned stores. The land is use chiefly for cattle-grazing, although hay and grain (barley, oats, an wheat) are cultivated in small areas.

The Pinnacles National Monument lies to the south, extending short distance into the southwestern part of the quadrangle.

The San Benito quadrangle is readily accessible by roads runnin parallel with its two main northwest-trending valleys, the San Beni River and Tres Pinos Creek. State Highway 25, a good paved roa runs through the area from Hollister in the northwest to Bitterwat in the southeast. This is part of the ''Airline Route'' from San Fra cisco to Los Angeles, via Hollister, Priest Valley, Coalinga, and Ta

The other main road is the ''Panoche Pass road,'' State Highwa 180, which extends from Paicines along Tres Pinos Creek, acro

anoche Pass, into Panoche Valley. In former years stagecoaches raveled this route from the New Idria mines to San Juan Bautista. andits are said to have frequented the route, among them the notoious Tiburcio Vasquez. Highway 180 is for the most part an nproved dirt road, but the section extending through the Franciscan n Tres Pinos Creek has long been known as the "Wiggletail," because f its narrow, winding, steep grades.

Climate

The climate of the San Benito region is semiarid. It is transitional etween that of the more humid Santa Lucia Range lying along the acific Coast to the west, and the arid Panoche Valley and western order of the San Joaquin Valley to the east. Precipitation is almost ntirely in the form of rain, and is confined largely to the winter and ring months. The average annual rainfall at Hollister is 13 inches; ne mean for San Benito County is estimated to be 16 inches (Anonyous 38, p. 20). The temperature falls below freezing for short periods uring the winter months, and reaches 80° to 100° F. in summer.

Vegetation

The natural vegetation of the San Benito quadrangle may be ivided into various types which show decidedly the influence of geogical as well as nongeological factors in their distribution. In some laces a formation may almost be mapped by its distinctive type of egetation. However, in other places formational contacts show no nfluence upon the vegetation, and vegetation contacts may occur where here is no apparent change in geological conditions. Permeability eems to be the most important geological controlling factor. The harpest vegetative changes not related to geology are produced by the ifferences between relatively southerly and northerly slopes; other ongeological factors are differences in elevation and relative steepness f slope.

In the course of geological mapping the writer noted five main lasses of vegetation whose distribution was notably influenced by eological factors. These are:

(1) *Grassland* (annual grasses and herbs). Grassland alone, barn of trees, occurs chiefly on clays and clay-shales, such as the Knoxille and Paskenta formations, and on parts of the San Benito gravels, rraces, landslides, and alluvium.

(2) *Savanna.* This type includes various species of live oaks, cattered among annual grasses and herbs, and also some conifers at he higher elevations. It is the most widespread vegetative type and ay occur in various geological environments, including:

(a) Southerly slopes of clays and shales, such as those of the Panoche group, Lodo formation, Kreyenhagen shale, Temblor shale, Monterey group.

(b) Northerly slopes of sandstones, such as the Panoche, Temblor, Santa Margarita, and Etchegoin.

(c) Formations producing a relatively thick soil cover, such as the Franciscan; and moderately unconsolidated deposits, such as the basal red beds of the Etchegoin, and the San Benito gravels.

(3) *Sagebrush and related low brush.* This occurs chiefly on sandstones, such as the Tres Pinos, Monterey, Santa Margarita, and Etchegoin. It also occurs on the sandy soil formed by granite. This type of brush is less dense than the two succeeding types.

(4) *Chaparral.*

(a) *Scrub oak and related brush.* Dense growths of scrub oaks, wild cherry, and related brush are most characteristic of the northerly slopes of shales, such as the Lodo, Kreyenhagen, and Temblor.

(b) *Chamise and manzanita.* Chamise and scattered manzanita form the densest brush cover in the region, parts of which are nearly impenetrable. They occur chiefly on the southerly slopes of sandstones, such as the Panoche, Temblor, and part of the Etchegoin; and also the sandy soil derived from granite.

PREVIOUS LITERATURE

The first mention of any part of the San Benito region was made by the English sea-captain, George Vancouver, on an exploring trip to the Pacific Coast in 1794. While waiting for his ships to be repaired at Monterey, he journeyed up the Salinas Valley as far as the Pinnacles where he "was there gratified with the sight of the most extraordinary mountain" he had ever beheld (Vancouver 94, p. 334). His journal includes a sketch of the Pinnacles made by one of his party.

Whitney and Brewer traversed the San Benito quadrangle while en route to the New Idria quicksilver mine in 1861, and both noted the unusual thickness of gravels (San Benito gravels) exposed along Tres Pinos Creek (Whitney 65, pp. 52-53; Brewer 30, pp. 135-138). Lawson further noted these gravels in 1893 (Lawson 93b, pp. 151-153).

Some of the reports of the California State Mining Bureau covering parts of the San Benito quadrangle include those by Irelan (88 pp. 483-490; 93, pp. 370-373), Fairbanks (94), Forstner (03, pp. 125-149), Bradley (18, pp. 101-102), Bradley and Logan (19), Vander Leck (21, pp. 69-70), Boalich (22), and Laizure (26). Fairbanks' paper includes three cross-sections of parts of the San Benito quadrangle.

Robin Willis made a physiographic study of part of the San Andreas fault in 1924, which includes a generalized geologic map of part of the San Benito quadrangle (Willis 24; 25). The most important previous geologic investigation is that of Kerr and Schenck (25). Their published map on a scale of 4 miles to 1 inch covers approximately the northwest one-third of the San Benito quadrangle.

The Pinnacles National Monument was studied by Andrews (36). His published map chiefly covers the adjoining Metz quadrangle to the south, but overlaps northward about 1 mile into the southern part of the San Benito quadrangle. Parts of the Priest Valley and Panoche quadrangles adjoining the San Benito quadrangle on the southeast and east were mapped by Mielenz (39). Other nearby areas to the southeast have been mapped by Pack and English (14) and to the east by Vokes (39).

GEOMORPHOLOGY

The California Coast Ranges are a series of ranges trending northwestward, parallel with the general structural trends of their underlying rocks. The individual ranges trend more nearly westward than the belt of ranges as a whole, so that they are successively truncated on the west by the Pacific Ocean. In the latitude of San Benito County the Coast Ranges have the following major divisions, starting from the coast at the west: the Santa Lucia Range, the Salinas Valley, the Gabilan Range, the Hollister Basin or San Benito Valley, and the Diablo Range. Parts of the Gabilan and Diablo Ranges comprise the San Benito quadrangle. Their dividing line is distinct in the vicinity of Hollister, where they are separated by a broad valley, but becomes less distinct to the southeast. The geologic boundary between the characteristic rock complexes of the two ranges is formed by the Bear Valley fault and in part by the San Andreas fault zone.

The San Benito quadrangle has several drainage systems. The most important is the San Benito River system which flows northwest into the Pajaro River near Hollister, and thence into Monterey Bay. Tres Pinos Creek, which drains nearly all of the northern half of the quadrangle, forms a subsidiary system, but joins the San Benito River southeast of Hollister. The southwestern part of the quadrangle is drained by Chalone Creek, which flows southward, then southwestward across the Gabilan Range, and empties into the Salinas River near Metz. The Salinas River flows northward into Monterey Bay. A small part of the eastern edge of the quadrangle, from Panoche Pass south to Bitterwater Creek, is drained to the east into the Panoche Valley and San Joaquin Valley.

The drainage pattern is in general irregular, varying from subdendritic to subtrellis, depending upon the underlying rock. The San Benito River in general has a subsequent course, parallel to the northwest-trending structures of the region, except for two step-like breaks (at San Benito, and at Sulphur Creek), in each of which it is shifted about 2 miles to the west. Tres Pinos Creek is roughly subsequent, paralleling strikes in the Franciscan and the San Benito gravels, except for the stretch between Las Aguilas Creek and Emmett School, where it cuts across the strike and is entrenched in a narrow, steep canyon. This part of its course is thought to have been superimposed from a cover of San Benito gravels. Bear Valley also has a rudely subsequent course. The upper part of its drainage has been captured by a stream running northwest into Willow Creek. Most of the other streams in the area are consequent, although a few, such as Paynes Creek, may be superimposed.

Cycles of Erosion

The San Benito quadrangle shows evidence of at least two cycles of erosion. The first cycle reached a stage of late maturity, represented by broad alluviated valleys and well-rounded ridges preserved in the higher elevations of both the Gabilan and Diablo Ranges. These valleys have been entrenched and destroyed over large areas by actively downcutting streams in V-shaped canyons representing the second or present cycle, which is still in a stage of youth, or, in part, of early maturity. The second cycle may, in places, be divided into two substages.

Gabilan Range

A number of broad, late mature valleys representing the first cycle of erosion are situated near the crest of the Gabilan Range, at an elevation of 2,000 to 2,500 feet. Most of these lie west of the San Benito quadrangle in the Gonzales quadrangle. Most notable are Gloria Valley, Williamson Valley, and the heads of Willow Creek and the South Fork of Willow Creek. In the San Benito quadrangle, Chalone Creek and Bickmore Canyon, draining toward the east, descend rather abruptly into steep, narrow, V-shaped youthful canyons which contrast strongly with the broad valleys at their heads. Obviously the broad valleys at the crest of the range could not have been formed by the present erosion cycle but are instead being destroyed by it. Both cycles are developed in granite, so that the factor of differential erosion may for the most part be eliminated.

Longitudinal stream profiles (fig. 2) constructed along Chalone Creek, Bickmore Canyon, and the two forks of Willow Creek clearly show the boundaries separating the two cycles by definite "knick points" (Knopf 24, p. 636). Subsidiary knickpoints along some of these canyons indicate two substages of the second cycle. It should be understood that knickpoints may also be caused by differences in resistance of rocks, as illustrated on the profile of Paynes Creek. However, in the cases mentioned above the rock is the same on either side of the knickpoints.

Diablo Range

Remnants of the first cycle of erosion in the Diablo Range are preserved chiefly in the northern third of the quadrangle. These comprise a number of broad alluviated valleys, including Browns Valley, Los Muertos Valley, Coyote Valley, Dairy Flat, Las Aguilas Valley, Slacks Valley, Lankford Flat, three unnamed valleys north of La Aguilas Creek, and a broad flat area south of Sugarloaf. Some of these valleys contain poorly drained, swampy areas. They are being entrenched and drained in their lower portions by youthful V-shaped canyons. Both cycles here are developed in sandstones and shales of the Franciscan group; differential resistance to erosion was not instrumental in determining the position of the broad valleys.

Longitudinal stream profiles of Las Aguilas Creek and Los Muertos Creek show definite knickpoints at boundaries between the two cycles. Tributaries to these streams possess "hanging valleys" where they pass from the first cycle of the tributary valleys to the second cycle.

In the Diablo Range south of Tres Pinos Creek the first cycle cannot be distinguished with certainty. This part of the area is in general stage of late youth or early maturity. A surface of low relief, tilted toward the northwest, is preserved on the Call Mountain. Although this surface might be correlated with the first-cycle valleys of Las Aguilas region, it seems more likely that it may be a surface formed below the San Benito gravels and preserved when the gravels were stripped off. The inclination of the gravels immediately to the west is essentially parallel with the tilt of this surface.

Big Oak Flat at the head of Paynes Creek is evidently a remnant of an earlier cycle of erosion, which may or may not be a correlative of the first cycle of Las Aguilas region. It is an alluviated valley

ntrenched on the northwest by Paynes Creek. Its southeastern part as been steeply entrenched and captured by Horsethief Canyon, hich has a much steeper gradient.

STRATIGRAPHY

Stratigraphic Provinces

The San Benito quadrangle may be divided into three stratigraphic rovinces, based upon the present distribution of the formations. The abilan Range to the southwest has a granite basement overlain by liocene sediments and volcanics. The Diablo Range to the northeast as a Franciscan (Upper Jurassic) basement, overlain by two different equences of younger formations. In the eastern part of the area is he Butts Ranch syncline, with a great thickness of Cretaceous, middle nd upper Eocene, and middle Miocene sediments. Between the Butts anch syncline and the Gabilan Range is the San Benito River area, n which the Franciscan is overlain by upper Miocene and Pliocene ediments. Related to the Butts Ranch syncline and not considered a eparate province is the Browns Valley area in the northwest part of he quadrangle which contains, in addition to Franciscan and Creta- eous, two middle Eocene formations. Plio-Pleistocene nonmarine sedi- ents overlap various parts of the entire region.

Stratigraphic columns are presented for each of the three main tratigraphic provinces—the Gabilan Range, San Benito River area, nd Butts Ranch syncline (figs. 3, 4, 5). Formations from the different reas are described together in the succeeding pages in order of decreas- ng age.

Gabilan Limestone (Pre-Santa Lucia Granite)

The oldest formation in the region is the Gabilan limestone (Becker 8, p. 181), considered a member of the Sur series (Trask 26, p. 134). his occurs as isolated roof pendants in the Santa Lucia granite, and lso as a fault breccia along the San Andreas fault zone. Only one roof endant, less than 100 feet wide, was found in the San Benito quad- angle, in the Chalone Creek region; but several outcrops occur to the outh in the Metz quadrangle (Andrews 36, p. 7). Fairly large areas f the limestone are exposed near Fremont's Peak to the northwest n the San Juan Bautista quadrangle.

The rock is a white to bluish-gray, thoroughly recrystallized arble, often exhibiting a faint banding. The largest mass of fault reccia, 1½ miles long and 500 feet wide, occurs southwest of the San enito River between the Jungle Inn and Willow Creek School. Two maller exposures occur farther southeast along the San Andreas fault one. The fault breccia consists of angular fragments of crystalline imestone, 3 or 4 inches to 50 or more feet in diameter, firmly cemented nto a resistant mass which forms prominent outcrops. Where exposed ver a fairly large area, it supports a dense growth of chaparral (cha- nise and manzanita).

The Gabilan limestone is older than the Santa Lucia granite; therwise its age is conjectural. From comparisons with Sierran for- nations and geologic history, Taliaferro (41, p. 123) concludes that ll the available evidence concerning the Coast Range basement-complex

rocks (of which the Gabilan limestone is a part) points to their being older than Upper Paleozoic: "They may be Lower Paleozoic or pre-Cambrian or both."

Santa Lucia Granite (Pre-Franciscan)

Intrusive into the Gabilan limestone is the Santa Lucia granite (Lawson 93a, p. 6). This is chiefly biotite granite, with some more basic phases, extensively intruded by aplite and pegmatite dikes. The granite comprises most of the northern part of the Gabilan Range, and is exposed over an area of 15 square miles in the southwestern part of the San Benito quadrangle. Two isolated outcrops occur as fault slivers along the San Andreas fault zone. The granite is highly jointed, usually deeply weathered and poorly exposed. It weathers to a reddish brown arkosic soil, and forms rounded slopes. It supports a growth of dense brush, either chamise or sagebrush type, which is thickest on southerly slopes.

The most common type of rock is a coarse-grained biotite granite (average grain size 2 to 5 mm), containing large flesh-pink orthoclase crystals. Microscopically the feldspars are seen to be chiefly orthoclase in part microperthite, and subordinate microcline. Myrmekitic intergrowths of vermicular quartz and untwinned feldspar are common. Plagioclase is subordinate, varying from basic albite to oligoclase ($Ab_{90}An_{10}$ to $Ab_{80}An_{20}$). It exhibits both albite and Carlsbad twinning. The feldspars show partial alteration to kaolin and sericite. Quartz, making up 25 to 40 percent of the rock, is highly granulated, showing mosaic structure and undulatory extinction. Biotite usually comprises 10 percent or less of the rock. Both brown and green varieties are present. The former is pleochroic with X, light yellow, Y and Z, deep golden brown; the latter shows X, greenish yellow, Y and Z, dark green. The biotite has been partially altered to chlorite. The minor accessories are magnetite, zircon, and apatite. More basic rocks carrying more plagioclase, less quartz, and hornblende as well as biotite, approach quartz monzonite or granodiorite in composition.

Numerous aplite and pegmatite dikes intrude the granite. They range in width from a few inches to several feet. The pegmatites are composed chiefly of flesh-pink orthoclase (in part microperthite) and quartz, sometimes in the form of graphic intergrowths. Plagioclase (albite to oligoclase) is rare. Muscovite is the only important accessory, and some magnetite is present. Some of the pegmatites are granulated and crossed by microscopic veinlets and stringers of calcite. The aplite consists of fine-grained flesh-pink orthoclase and quartz, and subordinate plagioclase.

Most contacts with the Santa Lucia granite in this area are faults. In the Willow Creek area, however, the basal shale of the Monterey and elsewhere the Miocene rhyolite, rest directly on the granite. The granite is extensively intruded by rhyolite dikes in the extreme southwestern part of the quadrangle.

Beyond the fact that it is pre-Franciscan, the age of the Santa Lucia granite is unknown. All known contacts between the granite and the Franciscan are faults; but various lines of evidence that the granite is older than the Franciscan were pointed out by Lawson (1

). 7). Taliaferro (41, p. 123) considers that the granite is probably lder than Upper Paleozoic.

Franciscan Group (Upper Jurassic)

The Franciscan group (Lawson 95, p. 347) is a heterogeneous eries of arkosic sandstones, shales, occasional conglomerates, radiolarian cherts, and pillow basalts or "greenstones." It is intruded by ultra-basic rocks, altered to serpentine, which have locally produced ontact aureoles of glaucophane and actinolite schists. The cherts and basalts are less abundant than in some other areas, and probably more han 90 percent of the group here consists of unmetamorphosed interedded sandstones and shales. The only lithologic type reported elsewhere but missing here is limestone. The Franciscan rocks vary in heir resistance to erosion and form a characteristic "knobby" topogaphy. They support a growth of oaks and grasses, and chaparral on ome of the schist areas.

Franciscan rocks cover the entire northeastern quarter of the San Benito quadrangle. This is only part of a large Franciscan area which extends to the north and forms most of the central portion of the Diablo Range. Discontinuous narrow strips of Franciscan have been brought to the surface farther southwest in the quadrangle, along hrust-faults, such as the San Benito, Pine Rock, and Bear Valley faults. Occasional patches are also exposed along the San Andreas fault zone. Franciscan rocks probably form the basement for the ntire area northeast of the Bear Valley fault.

The thickness of the Franciscan group is usually difficult to estinate because of strong folding and the lack of exposures of the base nd top. However, a fairly regular section across the north limb of a syncline is exposed along Las Aguilas Creek. Here a minimum thickness of 10,000 feet was measured, and neither the base nor top was exposed.

Sandstone is the most abundant rock in the Franciscan group. It s bluish gray or bluish green when fresh, weathering to greenish brown or yellowish brown. The structure varies from massive to well bedded nd platy. Poor sorting and great angularity of grain are noticeable features. The constituents are quartz and feldspars, about equally livided; rock fragments, chiefly black shale; and various minor accesories, including biotite, muscovite, magnetite, zircon, sphene, and epidote. The grains are separated by finely divided chloritic and seriitic material. The feldspars are chiefly plagioclase (andesine and oligoclase), subordinate orthoclase and occasional microcline. The sandstone is commonly traversed by small calcite and quartz veinlets, especially in the vicinity of ultra-basic intrusives. Adjacent to some of the intrusives, the sandstone becomes increasingly friable and is bleached to light shades of pink and purple, or almost to white. These changes are attributed to hydrothermal alteration.

Interbedded with the sandstones are thin, hard, platy clay-shales, black or bluish-gray in color, which grade into sandy shale and shaly sandstone. Carbonaceous material and unidentifiable plant remains are often present.

Franciscan conglomerates are rare in this area. They most commonly contain fine pebbles, ¼-inch or less in diameter, composed of black shale and chert fragments evidently derived from the Franciscan itself. A lens of coarse conglomerate 30 feet thick occurs 1 mile northeast of the mouth of Antelope Creek. It contains in a sandstone matrix subrounded to well-rounded pebbles averaging 2 to 3 inches and ranging up to 18 inches in diameter. The pebbles are chiefly porphyries (including feldspar, quartz-feldspar, and quartz porphyries), black cherts, and black fine-grained quartzites. Similar pebbles are found in nearly all succeeding conglomerates in this region, from Cretaceous to Pleistocene, but the rocks from which they were derived are nowhere exposed in the Coast Ranges. Probably many of the pebbles were reworked from one conglomerate to the next. In this report they are referred to as the "pre-Franciscan" type of pebble. Other constituents of the Franciscan conglomerate lens are a few sandstone pebbles of Franciscan origin, which are less rounded than the pre-Franciscan pebbles.

Lenses of radiolarian chert are interbedded with the other Franciscan sediments. They may be massive or well bedded, with thin partings of clay-shale; they are commonly contorted and crumpled. The color of the well-bedded types is generally red or green, of the massive varieties more commonly white or gray. Black manganese oxide stains occur along some of the bedding-planes and joints. The chert lenses thicken and thin abruptly, ranging from a few feet to several hundred feet in thickness. None could be traced for more than half a mile along the strike. The cherts represent chemical precipitates of silica, most likely contributed to the water by submarine volcanism (Taliaferro 33). The petrography of the chert has been described by Davis (18b).

Small lenticular outcrops of pillow basalt or "greenstone" occur in the Franciscan, often closely associated with the chert lenses. The rock is generally massive, greenish in color, and highly altered. Ellipsoidal pillows 2 to 3 feet in diameter are present locally. Although most of the basalts are roughly concordant with the adjacent sediments some show slightly cross-cutting intrusive relationships; others may represent submarine flows. Veinlets and amygdules of quartz and calcite are common. Saussuritized feldspar and occasional augite phenocrysts are the only constituents ordinarily recognizable with a lens. A microscopic study of one sample revealed phenocrysts of augite in an intersertal groundmass composed of lath-shaped feldspars and smaller equidimensional augite crystals separated by a matrix of dark-gray, devitrified glass. Magnetite is common in the groundmass and in veinlets. Veinlets and patches of green chloritic material occur in addition to quartz veinlets.

Masses of serpentine intrude the other rocks of the Franciscan group. They are products of hydrothermal alteration of ultra-basic rocks such as peridotite and dunite. They are colored green or bluish green. One common variety is massive, and has numerous slickensided and polished surfaces; another is coarsely crystalline, containing bastite pseudomorphs of orthorhombic pyroxenes. Narrow belts of serpentine have been squeezed up along some of the faults, such as the

Pine Rock and San Benito faults, in the form of "cold intrusions." The largest masses of serpentine occur in the Tres Pinos Creek area north of the Bradford mine, where they are surrounded by aureoles of glaucophane and related schists. Serpentine is rare in the rest of the main Franciscan belt. The observed intrusive serpentines are obviously younger than the Franciscan sediments, but evidence of more than one period of intrusion is furnished by the presence of serpentine as a detrital mineral in the Franciscan sandstone, and the presence of both serpentine and glaucophane schist pebbles in Franciscan conglomerates (Davis 18a, pp. 20, 25).

An alteration product of serpentine known as silica-carbonate rock occurs along some of the faults in the San Benito quadrangle. It is a resistant rock, reddish to brownish in color, consisting of a mixture of chalcedony, quartz, and various carbonates in a myriad of interpenetrating veinlets. Similar rocks were attributed by Knopf (06) to hydrothermal alteration of serpentine.

A series of glaucophane, actinolite, and related schists has been developed by pneumatolytic contact metamorphism of the Franciscan sediments and volcanics around serpentine intrusions. The largest mass, about 4 miles long by 1 mile wide, occurs north of the Bradford fault near Tres Pinos Creek. A variety of types is represented, the most common being glaucophane-quartz-albite, glaucophane-albite-sericite, actinolite, and actinolite-albite schists. Other minerals commonly present are chlorite, garnet, epidote, sphene, magnetite, and biotite. An interesting type is that derived from chert. This consists of a granoblastic aggregate of quartz, showing mosaic structure and strain effects, and scattered prismatic crystals of glaucophane. Other minerals present are chlorite, muscovite, garnet, in euhedral dodecahedral crystals, and sphene, in euhedral crystals. Introduction to the original chert of Na_2O, K_2O, Al_2O_3, and TiO_2 seems indicated.

Where these rocks are schistose, the schistosity is determined by the original bedding, not by directed pressure. Schistosity planes parallel the bedding planes of the unaltered sediments. The Tres Pinos syncline may be traced through a belt of glaucophane schists by the planes of schistosity.

The origin of the schists by pneumatolytic action accompanying the ultra-basic intrusions seems demonstrated by the proximity of the schists to these intrusive bodies, and by their gradation into unaltered sediments both along and across the strike. The distribution of the schists in detail is spotty, probably reflecting the presence or absence of favorable channels for pneumatolytic action. A glance at the geologic map will show the general relationship of the schist bodies to the serpentines, but the clearest-cut field relations are demonstrated by an isolated intrusive body along Las Aguilas Creek [1] which is too small to represent on the map. Here a thin serpentine sill intruded into sandstone and shale has produced a narrow zone of glaucophane schist on either side. Surrounding this zone in all directions are thousands of feet of unaltered sandstones and shales. The sandstone strikes N. 50° W., dips 70° SW., and the serpentine sill and schistosity in the schist

[1] SE¼ SW¼ sec. 28, T. 14 S., R. 8 E., M. D.

zone have attitudes essentially parallel with this. The various zones noted here, from south to north, are:

	Thickness (feet)
(a). Normal Franciscan sandstone. Fine-grained; grayish to greenish	--
(b). Shale zone, partially altered. Has a glossy appearance, bluish color, showing development of fine-grained glaucophane	7
(c). Serpentine sill. Green, highly crumpled appearance. Filled with calcite veins. Slickensided and sheared surfaces	58
(d). Glaucophane schist. Fine-grained, schistose (probably from shale) to coarse-grained, granulose (probably from sandstone). Deep blue color. Shows glaucophane, albite, garnet; abundant veinlets of calcite	18
(e). Glaucophane and actinolite schist, cut in two places by small lens-like bodies of serpentine	9
(f). Zone of slightly altered shale, similar to (b); glossy, bluish appearance; interbedded with practically unaltered greenish sandstone	14
(g). Normal Franciscan sandstone, cut by few veinlets of quartz	--

The Franciscan sediments are dominantly clastics deposited under shallow-water, marine conditions in a sinking geosyncline. The abundance, freshness, and angularity of feldspar grains in the sandstones indicate fairly rapid transportation from a land mass in which mechanical disintegration dominated. From a study of the coarsening of Franciscan sediments, Taliaferro (41, p. 124) concludes that this land mass lay to the west of the present Pacific coast line.

The only contact of the Franciscan with older rocks is with the Santa Lucia granite along the Bear Valley fault. The base of the Franciscan has nowhere been seen. Most of the contacts with younger rocks are fault contacts, except for many of those with the San Benito gravels which are depositional.

The age of the Franciscan is now definitely established as Upper Jurassic. The most important fossils yet found are two ichthyosaur rostra in worn chert cobbles, reported by Camp (41). They indicate either an Upper Jurassic or Lower Cretaceous age, but there is abundant physical evidence against the latter possibility. Taliaferro (42) has established independent physical evidence of an Upper Jurassic age, based upon relationships to the equivalents of the Sierran Jurassic formations in northern California and southwestern Oregon.

Knoxville and Paskenta Formations, Undifferentiated (Upper Jurassic and Lower Cretaceous)

The Knoxville and Paskenta formations (White 85; Anderson 02, pp. 43-47) consist chiefly of dark clay-shales with gray limestone concretions, and occasional interbedded greenish-brown sandstones. The shales are black to greenish black, soft, usually well bedded in layers 2 to 3 inches thick. Carbonaceous material is common. The abundant limestone concretions are usually fairly round, and may reach a diameter of 3 to 4 feet. The interbedded sandstones are poorly sorted, rich in feldspar and biotite, and usually thin-bedded and platy. The formations as a whole are very soft and form low, well-rounded hills, with numerous small slumps and mud-flows. The main vegetation is grass and widely scattered oaks.

The Knoxville and Paskenta are exposed in a long, discontinuous, arrow belt along the San Benito fault zone. They occur chiefly on he northeast or upthrust side of the fault, but appear occasionally in zone between two or more branching faults. The thickness appears to e at least 500 feet. The formations are lithologically identical and nseparable in the field. Their base is not exposed, but they are overain depositionally by the Panoche group in the southeastern part of he area. Although there is no exact paleontologic control for this pper contact, the lithologic boundary more or less arbitrarily chosen as a marked expression in the topography and vegetation. The overying Panoche sandstone and shale produces steeper, more rugged lopes, with more numerous outcrops, and tends to support sagebrush r other low brush as well as numerous oak trees.

Abundant, well-preserved Aucellas collected by the writer from a imestone concretion were referred by both F. M. Anderson and S. W. Muller to the *Aucella piochii* group, supposedly characteristic of the Knoxville formation, Upper Jurassic. However, N. L. Taliaferro[2] eports specimens of the *Aucella crassicollis* group, in addition to the *Aucella piochii* group, from approximately the same locality. H. G. Schenck[3] also reports the *Aucella crassicollis* group from the same icinity. This group has been considered characteristic of the Paskenta ormation, Lower Cretaceous. N. L. Taliaferro suggests that the *Aucella crassicollis* group may extend down into the Knoxville, conrary to the general opinion. If this be true, perhaps only the Knoxille is represented in this area; but if the traditional ideas regarding he ranges of these fossils are correct, Knoxville and Paskenta may be uxtaposed without an actual contact being visible. The section is poorly exposed and is in a highly faulted area; a contact between the wo formations is difficult to find at best, because of their lithologic imilarity.

Panoche Group (Upper Cretaceous)

The Panoche group (Anderson and Pack 15, p. 39) consists of 5000 to 9000 feet of brownish concretionary arkosic sandstones; interbedded dark clay shales, greenish sandstones, and limestones; and lesser thicknesses of platy purplish calcareous foraminiferal shales. All are of shallow marine origin. Megafossils are rare, but Foraminifera are rather abundant. Both indicate an Upper Cretaceous age.

The Panoche group is exposed on both limbs of the Butts Ranch syncline, for a distance of about 9 miles. The two belts thus formed continue to the southeast beyond the limits of the quadrangle, and are overlapped to the northwest by the San Benito gravels. The southwest belt has a thickness of 7000 to 9000 feet; the northeast belt 5000 to 3000 feet. A separate mass of Panoche beds, with an exposed thickness of more than 4000 feet, occurs in the northwest part of the quadrangle, in the Browns Valley region, where it is in fault contact with the Franciscan to the north and the Eocene Los Muertos Creek formation to the south.

The Panoche group is in contact with the Franciscan along the northeast flank of the Butts Ranch syncline. This contact is a fault

[2] Personal communication, March 1941.
[3] Personal communication, February 1941.

as far east as Chemise Ridge, but east of that point it appears to be depositional. The contact dips to the south as gently as 35° in Paynes Creek, essentially parallel with the dip of both the underlying and overlying beds. No basal conglomerate containing Franciscan debris was found; the Panoche consists of interbedded shales and sandstones right at the base. The contact must necessarily be unconformable, since the Knoxville and Paskenta formations are not represented. The Panoche group rests upon the Knoxville and Paskenta formations along the southwest side of the Butts Ranch syncline, although the contact could not be located with certainty. It is presumably unconformable since the intervening middle Cretaceous Horsetown formation is missing.

The lithologic members of the Panoche group vary in their influence upon topography and vegetation. The shales, and interbedded sandstones and shales, offer little resistance to erosion and form low well-rounded slopes. They support oaks and grass, or occasionally low brush of the sagebrush type. The massive sandstones, in contrast, are among the most resistant rocks of the area and form prominent ridges and cliffs. They underlie the high parts of the Call Mountains, Big Mountain, and Pine Ridge. They support a dense growth of chaparral (chamise and manzanita) particularly on southerly slopes.

The Panoche group may be separated into several broad lithologic members, some of which possess distinctive faunas. These units, however, are not constant in all of the three belts exposed in the quadrangle. On the northeast side of the Butts Ranch syncline three divisions were made:

	Thickness (feet)
3. *Butts Ranch shale member.* Foraminiferal calcareous purplish shale	100– 300
2. *Call sandstone member.* Massive brownish concretionary sandstone	2600–2900
1. *Paynes shale and sandstone member.* Interbedded dark-colored clay-shale, greenish sandstone, and limestone	2100–3200

The following divisions were made on the southwest limb of the syncline:

	Thickness (feet)
4. *Big Oak Flat shale and sandstone member.* Interbedded brownish sandstone and clay-shale, with limestone concretions, overlain by foraminiferal clay-shale	500– 700
UNCONFORMITY—	
2. *Call sandstone member.* Massive brownish concretionary sandstone	0–1200
1. *Paynes shale and sandstone member.* Interbedded dark-colored clay-shale, greenish sandstone, and limestone	5200–8500

An unconformity between units 2 and 4 above cuts out 1200 feet of the Call sandstone member within a horizontal distance of 1¼ miles. A difference in strike of 12° between the two members shows clearly on aerial photographs. The Butts Ranch shale member is not represented on the southwest side of the syncline. The Big Oak Flat shale and sandstone member cannot be placed definitely with respect to the

equence on the northeast limb of the syncline. It is thought to be ounger than the Butts Ranch shale member because of its uncon- ormable position on the Call sandstone member. The Panoche group f the Browns Valley area is not divisible into lithologic units, but most esembles the Paynes shale and sandstone member of the Butts Ranch yncline.

aynes Shale and Sandstone Member

The Paynes shale and sandstone member is herein named for aynes Creek, and the type locality is the section along Paynes Creek ½ miles north of Butts Ranch, where the thickness is 2100 feet. A reater thickness of 5200 to 8500 feet is found on the southwest side of he Butts Ranch syncline. The type locality was chosen for the superior uality of the exposures of the member, and of its relationships to the urrounding beds. The member consists largely of interbedded dark- olored clay-shales, greenish sandstones, and limestones. The shales re typically greenish to black clay-shales or poorly sorted silty nicaceous shales. They are well-bedded in layers ½ to 2 inches in hickness, and are commonly rhythmically interbedded with thin-bedded andstone or limestone. Carbonaceous material is common. The sand- tones are poorly sorted, arkosic and strongly biotitic, greenish to rownish in color. They occur in well-cemented beds a few inches to feet in thickness. The limestones are generally grayish in color, and ccur as concretions or in small lenses a fraction of an inch to a few nches in diameter.

In the middle of the section in the Browns Valley area a conglom- ratic layer about 150 feet thick can be traced for at least half a mile. he pebbles are subrounded to well rounded, ½ to 18 inches in diameter, veraging 3 to 6 inches. They are chiefly of the pre-Franciscan type of orphyries and quartzites. A study of 100 pebbles revealed the follow- ng proportions:

Gray feldspar porphyry	45
Quartz-feldspar porphyry	12
Pink biotite-feldspar porphyry	1
White and pinkish-white quartzite	15
Black quartzite	6
Black chert	4
Milky vein quartz	1
Breccia (?)	6
Fine-grained granodiorite	1
Undetermined	9

In the section on Paynes Creek on the northeast side of the Butts Ranch syncline occurs a thin conglomerate layer of scattered pebbles n a sandstone matrix. About 6 to 10 pebbles are exposed per square foot. They are well rounded, average 1 to 2 inches in diameter, and are he usual pre-Franciscan porphyries, black cherts, and quartzites.

Fossils from Tres Pinos Creek, near the middle of the Paynes shale nd sandstone member, were identified by F. M. Anderson as *Inocera- mus whitneyi* Gabb, *Anisomyon meekii* Gabb, and *Baculites* sp. He states that these are probably Panoche (Upper Cretaceous) in age.

Numerous pearly shell fragments and Foraminifera occur in a fine- grained carbonaceous sandstone layer 400 feet below the top of the Paynes shale and sandstone member on Paynes Creek. Megafossils include *Meekia radiata* Gabb, *Inoceramus* sp., and an unidentifiable

echinoid, "probably a spatangoid", according to Hubert Lyman Clark. The following Foraminifera occur at this locality:

Bathysiphon
Dentalina communis (d'Orbigny)
Eponides haidingerii (d'Orbigny)
Gaudryina crassaformis Cushman and Campbell
Glandulina manifesta Reuss
Globotruncana arca (Cushman)
Gyroidina sp.
Lenticulina navicula (d'Orbigny)
Lenticulina sublaevis Morrow
Lenticulina williamsoni (Reuss)
Marginulinopsis decurse-costata Thalmann
Marssonella oxycona (Reuss)
Nodosaria affinis Reuss
Robulus velascoensis (White)
Spiroplectammina anceps (Reuss)
Stensioina cf. excolata (Cushman)
Ventilabrella ornatissima Cushman and Church

A dark-colored clay-shale interbedded with sandstone on Salt Creek yielded the following Foraminifera:

Bolivina incrassata ? Reuss
Bolivinopsis clotho (Grzybowski)
Bulimina trinitatensis Cushman and Jarvis
Gaudryina crassaformis Cushman and Campbell
Gyroidina cf. florealis White
Silicosigmoilina californica Cushman and Church
Arenaceous Foraminifera

According to Lois T. Martin, these are indicative of the Panoche (Upper Cretaceous).

Call Sandstone Member

The Call sandstone member is best developed on the northeast side of the Butts Ranch syncline, where it has a thickness ranging from 2600 to 2900 feet. It is here named for the Call Mountains, and the type locality is the section exposed through the Call Mountains on Paynes Creek 2 miles north of Butts Ranch. The member is also exposed on the southwest side of the syncline at the head of Buckeye Canyon, where it has a thickness of only 1200 feet; it is cut out completely toward the east by the unconformity with the overlying Big Oak Flat member. No fossils were found in the Call sandstone member but its age is delimited by fossiliferous Upper Cretaceous beds occurring on either side.

The member consists mainly of massive brownish concretionary sandstones, and some interbedded siltstones and clay-shale. The sandstones form prominent outcrops and cliffs. They are arkosic, poorly sorted, angular, and well cemented. In addition to quartz they contain abundant feldspars, biotite, and carbonaceous material. Heavy minerals present besides biotite are zircon, brown tourmaline, garnet, sphene, magnetite, and epidote. The sandstones have a grayish color when fresh, but are usually weathered brownish. They possess large reddish-brown "cannonball" concretions ranging from 2 to 10 feet in diameter.

Well-bedded siltstones and clay-shales are commonly interbedded with the sandstones of the Call sandstone member. The siltstones usually show fine banding caused by the orientation of biotite flakes and other dark minerals in thin layers. Many of the bands show cross bedding, a feature of great aid in determining the top sides of the strata. Graded bedding is often present, passing from sandstone

hrough siltstone to clay-shale, then starting abruptly again with sand-tone. One of the most interesting features of the siltstone is the occur-ence of intraformational contortion or corrugation (Hills 40, pp. 15-7) revealed by the dark banded layers. Some bands are extremely ontorted into asymmetric overturned and recumbent folds 6 to 8 nches high, although the boundaries of the siltstone bed against the djacent sandstone or shale remain parallel. The contortion is prob-bly due to sliding or slumping while the siltstone still contained water nd could act as a plastic mass.

A fairly persistent conglomerate about 100 feet thick occurs at the ase of the Call sandstone member on the northeast side of the Butts anch syncline. The pebbles are subrounded to well rounded, averag-ng 3 to 4 inches in diameter. They consist of the pre-Franciscan group f porphyries, black cherts, and quartzites.

utts Ranch Shale Member

The Butts Ranch shale member of the Panoche group is exposed nly along the northeast limb of the Butts Ranch syncline. It is amed for Butts Ranch, and the type locality is the section along aynes Creek 1 mile north of Butts Ranch. Here it has a thickness f 200 feet.

This member consists of purplish or brownish calcareous and clay-hales, which are abundantly foraminiferal. The shales are thinly edded, tend to be somewhat hard and platy, and are highly fractured. he shale member is cut at various angles by sandstone dikes 2 or 3 eet wide, composed of a brownish biotitic sandstone similar to the nderlying Call sandstone member.

The Butts Ranch shale member yielded the following assemblage f well preserved Foraminifera:

Anomalina cf. rubiginosa Cushman
Bolivina incrassata Reuss
Bulimina obtusa d'Orbigny
Epistomina caracolla (Roemer)
Eponides haidingerii (d'Orbigny)
Gaudryina crassaformis Cushman and Campbell
Globotruncana arca (Cushman)
Gyroidina depressa (Alth)
Haplophragmoides eggeri Cushman
Lenticulina williamsoni (Reuss)
Marssonella oxycona (Reuss)
Nodosaria ewaldi Reuss
Nodosaria cf. spinifera Cushman and Campbell
Planulina cf. schloenbachi (Reuss)
Pullenia coryelli White var.
Silicosigmoilina californica Cushman and Church
Spiroplectammina anceps (Reuss)
Ventilabrella ornatissima Cushman and Church

The faunal assemblage from the Butts Ranch shale member has been examined by Louis Simon, C. C. Church, Max B. Payne, and Robert T. White, all of whom state that it is indicative of the Panoche, and is definitely older than the Moreno at its type area.

Big Oak Flat Shale and Sandstone Member

The Big Oak Flat shale and sandstone member, which unconformably overlies the Call sandstone member, is exposed only on the southwest side of the Butts Ranch syncline. It is named for Big Oak Flat, and the type locality is the small northeast-trending canyon 1 mile northwest of Big Oak Flat. Here were found Foraminifera which established its Upper Cretaceous age.

The relation of this member to the formations on the northeast limb of the syncline can not be established definitely. Because of the unconformity at its base, it is thought to be younger than the Butts Ranch shale member. It may also be younger than the Moreno shale, which does not appear on the southwest side of the syncline. The Foraminifera, beyond indicating an Upper Cretaceous age, are not sufficiently distinctive to correlate it more closely. The member is overlain by the Lodo formation (middle Eocene).

The member consists of interbedded sandstone and shale with limestone concretions, having a thickness of 300 to 350 feet, overlain by 200 to 300 feet of foraminiferal clay shale. The sandstones are brownish, well-cemented, poorly sorted, and arkosic, containing an abundance of biotite. They occur in resistant beds 2 to 3 feet thick, separated by sandy shale, siltstone, and dark-colored clay-shales. Limestone concretions are common, appearing dark gray to black on fresh exposure but weathering light gray. Some of them contain molds of undeterminable pelecypods and gastropods. The foraminiferal shale at the top is a well-bedded clay-shale, somewhat calcareous, chocolate-brown to black in color.

The Big Oak Flat shale and sandstone member contains an assemblage of mainly arenaceous Foraminifera:

Arenobulimina ?
Bathysiphon
Bulimina
Gaudryina
Globigerina
Glomospira charoides (Jones and Parker)
Haplophragmoides
Marssonella ?
Nonion ?
Plectina cf. irregularis Marsson
Pullenia
Silicosigmoilina californica Cushman and Church
Spirillina vivipara Ehrenberg
Spiroloculina cretacea Reuss
Spiroplectammina dentata (Alth)
Trochammina globigeriniformis (Parker and Jones)
Trochamminoides
Radiolaria ? Lithostrobus

The slide containing this faunule was examined by Louis Simon who states: "My guess would be that your faunule is from the Upper Cretaceous probably not older than basal Coniacian."[4]

Moreno Shale (Upper Cretaceous)

The Moreno shale (Anderson and Pack 15, p. 46) is exposed in a narrow belt along the northeast side of the Butts Ranch syncline where it has a thickness of 300 to 650 feet. It is typically a purple thin-bedded platy siliceous and calcareous shale, interbedded with soft brownish clay-shale. Gray limestone concretions up to 6 feet in diameter are common. These contain numerous specimens of the foraminifer *Siphogenerinoides* which may readily be noticed by the naked eye. The shale is cut at random by sandstone dikes from 2 to 10 feet wide. These dikes are composed of a brownish arkosic biotitic sandstone identical with and probably derived from the underlying sandstone of the Panoche group. A few thin-bedded brownish sandstones are occasionally interbedded with the shale. The Moreno shale forms

[4] Letter to H. G. Schenck dated February 10, 1941.

ow belt of gently rounded grass-covered slopes, and supports a few ak trees, but no chaparral. It contrasts strongly with the overlying Call sandstone member which forms resistant slopes and is covered y chaparral.

The Moreno shale appears to rest conformably upon the Call sandtone member of the Panoche group along the northeast side of the Butts Ranch syncline.

The relationships to the Butts Ranch shale member and Big Oak Flat shale and sandstone member of the Panoche are in some doubt, as hese are nowhere in contact with the Moreno. The Butts Ranch shale nember also rests depositionally upon the Call sandstone member on he northeast side of the Butts Ranch syncline, farther south along Paynes Creek. The foraminiferal evidence indicates that it is older han Moreno. It is lithologically similar to the Moreno, and may ctually be included in the lower part of the unit which was mapped s Moreno, although no faunal evidence for its presence there was ound. The Big Oak Flat shale and sandstone member occurs only n the southwest side of the Butts Ranch syncline, where the Moreno s not exposed. It may actually be younger than the Moreno.

The Moreno shale contains abundant Foraminifera, belonging to a elatively few species:

Bulimina cf. prolixa Cushman and Parker
Cyclammina elegans Cushman and Jarvis
Cyclammina pusilla Brady
Haplophragmoides eggeri Cushman
Siphogenerinoides cf. whitei Church

These species, particularly the *Siphogenerinoides,* are characteristic f the type Moreno, Upper Cretaceous, according to H. G. Schenck and Max B. Payne. They state that the lithology and fauna at this locality orrespond to the Marca shale member (Payne 41) of the Moreno at the ype locality.

Los Muertos Creek Formation (Middle Eocene)

The name Los Muertos Creek formation is proposed for a series f siltstones, fine-grained buff micaceous sandstones, clay-shales, and herty shales exposed 2 miles northwest of Los Muertos Creek, west of Brown Valley, in the northwestern part of the San Benito quadrangle. The formation has an exposed thickness of about 1000 feet. It is exposed in a narrow belt trending northwest for a distance of 2 miles within the quadrangle. The base is faulted out against the Panoche group to the northeast. Los Muertos Creek formation is conformably overlain by the Tres Pinos sandstone to the southwest, and is overlapped to the southeast by the San Benito gravels. Fossils indicate that it belongs to the Capay stage, middle Eocene.

The formation consists chiefly of buff to brownish fine-grained sandstones and siltstones which are poorly indurated, highly jointed, and strongly weathered. The sandstones are somewhat clayey and micaceous. Near the top of the section there are a few layers 3 to 4 feet wide of massive, well-cemented, coarse-grained quartzose sandstone which are much more resistant to erosion than the rest of the formation. These are lithologically identical with the overlying Tres Pinos sandstone. Dark-colored clay-shales are occasionally interbedded with the

sandstones. Toward the bottom of the exposed section, in the northeast corner of the Gonzales quadrangle, are some platy cherty shales in beds 2 to 8 inches thick. Foraminifera were revealed by the hand-lens, but they could not be separated from the hard shale for microscopic examination.

The formation is easily eroded, and forms low, well-rounded grass-covered slopes. It is poorly exposed except in canyons. It contrasts strongly with the overlying Tres Pinos sandstone which forms high resistant knobs exhibiting bare rock surfaces.

Abundant but poorly preserved fossils were found at one locality in a brownish siltstone in Los Muertos Creek formation. The following were identified by B. L. Clark and the writer:

ANTHOZOA
Turbinolia sp.

ECHINOIDEA
Schizaster diabloensis Kew

PELECYPODA
Gari ? sp.
Glycymeris ? sp.
Nemocardium linteum (Conrad)
Pitar sp.
Plagiocardium (Schedocardia) brewerii hartleyense? (Clark and Woodford
Solen sp.
Solena ? sp.
Trachycardium (Agnocardia) sorrentoense ? (Hanna)
Yoldia rosa ? (Hanna)

GASTROPODA
Amaurellina ? sp.
Bittium dumblei ? (Dickerson)
Ficopsis remondii (Gabb) crescentensis Weaver and Palmer
Turritella uvasana Conrad subsp.

ARTHROPODA
fragment of Crustacean

B. L. Clark states that this assemblage belongs to the Capay stage of the middle Eocene.

The formation just described was assigned to the Meganos formation by Kerr and Schenck (25, p. 475), but this was before the Capay stage had been separated in the California Eocene. H. G. Schenck who has examined the above faunal list, agrees that the formation might fall in the "Capay stage." A local formational name is preferred because there is no assurance that future subdivisions or groupings of the California Eocene may not place this assemblage of strata in some other stage, and, according to Schenck, the stratigraphic relations of the type Capay are not certain.

Tres Pinos Sandstone (Middle Eocene)

The Tres Pinos sandstone is a massive resistant coarse-grained quartzose sandstone exposed in a belt immediately overlying Los Muertos Creek formation northwest of Los Muertos Creek. The exposed thickness is about 900 feet, but the top of the formation is concealed by overlapping terrace deposits to the southwest and the San Benito gravels to the southeast. The sandstone is resistant to erosion, forming prominent ridges and knobs with bare rock surfaces. It supports a sparse growth of brush of the sagebrush type in addition to grass. A conglomerate occurs at the base containing fossils of Capay (middle

locene) age; however, the rest of the formation is non-fossiliferous nd may be slightly younger. The formation was named by Kerr and chenck (25, pp. 470-475) and the type locality was apparently the ection herein described.

The Tres Pinos consists entirely of well-cemented and resistant andstone and conglomerate. The sandstone is whitish on fresh expoure, but weathers to a buff or brownish color. It occurs in massive eds 10 to 15 feet thick, which are jointed and contain large erosional avities. The sandstone contains abundant quartz and subordinate eldspar in subangular to subrounded grains. A mineral analysis eveals zircon to be the most abundant heavy mineral, making up half r more of the heavy portion. Brown biotite and garnet are next in bundance. The presence of a small amount of glaucophane indicates he Franciscan as either a direct or reworked source for the formation. hlorite, epidote, green hornblende, magnetite, picotite, rutile, sphene, nd tourmaline are also present. The analysis is most nearly similar o one of the Yokut sandstone of the Butts Ranch syncline, except for he presence of glaucophane.

At the base of the formation is a well-cemented calcareous buff onglomeratic sandstone layer 10 to 15 feet thick which contains abunant poorly preserved fossils. This is a persistent horizon which was raced for 1½ miles. It contains small pebbles, averaging ⅛- to ½-inch ut ranging up to 3 inches in diameter. They consist chiefly of milky uartz, black chert, and gray limestone.

The Tres Pinos sandstone is barren of fossils except for the basal onglomerate, from which the writer collected chiefly poorly preserved elecypods, including *Pitar* sp. A better collection of gastropods made y H. G. Schenck in 1924 was loaned to the writer, and identified by . L. Clark as follows:

GASTROPODA

Rimella (Macilentos) macilenta White
Amaurellina clarki Stewart
Turritella andersoni Dickerson
Cryptochorda californica Cooper

These are indicative of the Capay stage, according to Clark. This ossiliferous conglomerate horizon was included by Kerr and Schenck 25, p. 475) in the formation immediately below the Tres Pinos, called y them Meganos, and herein named Los Muertos Creek formation. To he writer, however, it seems more proper to consider this horizon as he basal conglomerate of the Tres Pinos sandstone, because it is overain by a series of sandstones which are similar to the matrix of the onglomerate. Since the contact is conformable and gradational, howver, its placement is necessarily more or less arbitrary. The gradaional character is indicated by the fact that a few sandstone layers imilar to the Tres Pinos occur within the top portion of Los Muertos reek formation.

Although the age of the basal conglomerate is established as Capay, he rest of the sandstone could be somewhat younger, in the lack of ny faunal evidence. The formation cannot be correlated with cerainty with any of the Butts Ranch syncline section. It is lithologically ost nearly similar to the Yokut sandstone; however, it might be equivlent to the Domengine sandstone.

Lodo Formation (Middle Eocene)

The Lodo formation (White 38) is represented by about 300 feet o bluish-gray foraminiferal clay-shale occurring in a narrow belt alon the southwest side of the Butts Ranch syncline. It is poorly expose except in a small canyon running northeast of Hill 3603 on Pine Ridg Here Foraminifera which establish its age were collected.

The shale of the Lodo formation directly overlies the Big Oa Flat shale and sandstone member of the Panoche group. No actua contact between the two similar shale units was seen, and the boundar was arbitrarily placed between foraminiferal collecting localities estab lishing the age of the two formations. The Lodo is overlain, apparentl conformably, by the Yokut sandstone. The contact is sharply define but there is no apparent difference in attitude of the two formation

The Lodo formation offers slight resistance to erosion, and, togethe with the underlying Cretaceous shale, forms a low trough between th more resistant Yokut sandstone to the northeast and the Cretaceou sandstone along Pine Ridge. It supports a fairly dense growth brush of the scrub-oak type.

The following is a foraminiferal assemblage from near the top the Lodo formation:

Anomalina aragonensis Nuttall
Anomalina garzaensis Cushman and Siegfus
Asterigerina crassaformis Cushman and Siegfus
Bathysiphon eocenica Cushman and Hanna
Bolivinopsis directa (Cushman and Siegfus)
Bulimina cf. callahani Galloway and Morrey
Discorbis allomorphinoides (Reuss) of Plummer
Gaudryina coalingensis Cushman and Hanna
Globigerina bulloides d'Orbigny
Globigerina triloculinoides Plummer
Globorotalia n. sp.
Globorotalia crassata (Cushman)
Glomospira charoides corona Cushman and Jarvis
Gyroidina octocamerata Cushman and Hanna
Nodosarella ignota Cushman and Siegfus
Nonion wilcoxensis Cushman and Ponton
Pleurostomella cubensis Cushman and Bermudez
Pleurostomella nuttalli Cushman and Siegfus
Silicosigmoilina californica Cushman and Church

According to H. G. Schenck, this faunule is to be correlated wi a part of the type Lodo formation, or with division C of the Eoce classification of Laiming (40, pp. 550-551). The age is middle Eocer approximately equivalent to the "Capay stage."

Yokut Sandstone (Middle Eocene)

The Yokut sandstone is a massive quartzose sandstone unit expos along the southwest flank of the Butts Ranch syncline. Its thickn varies between 800 and 1200 feet. It conformably overlies the Lo formation, and is unconformably overlain by the Domengine sandsto

The formation is resistant to erosion, forming prominent outcro and is covered by a dense growth of chaparral (chamise and man nita), particularly on the southerly slopes.

The sandstone is unfossiliferous, but its position between two f siliferous horizons establishes its age as middle Eocene, probably equi lent to part of the Capay stage. Similar lithologic character and po tion in the sequence form the bases of correlation with the type Yok

amed by Robert T. White (40). The type locality is on the west side f the San Joaquin Valley north of Coalinga.

The Yokut consists nearly entirely of sandstone, which is well emented and resistant, and shows tendencies toward cavernous weathring. In places it is concretionary, bearing brownish sandstone conretions several feet in diameter. It is predominantly massive, but ometimes shows bedding planes spaced 10 to 15 feet apart. The ndstone is whitish on fresh exposures but weathers yellowish to rownish. It is better sorted than most of the sandstones in this region. he grains are subangular to subrounded, medium- to coarse-grained. he sandstone is quartzose, somewhat feldspathic, but relatively poor n biotite and other ferromagnesians. A mineral analysis reveals a aucity of heavy minerals, of which zircon is most abundant. Present n lesser quantities are garnet, sphene, brown tourmaline, epidote, magetite, and chlorite.

Domengine Sandstone (Middle Eocene)

The Domengine sandstone (Anderson 05, pp. 167-168; Clark and tewart 25), middle Eocene, is one of the most characteristic and ready mappable horizons of the Butts Ranch syncline. It is nearly everyhere abundantly fossiliferous, which distinguishes it from the adjacent ormations. It occurs on both sides of the syncline, from the eastern dge of the quadrangle to Salt Creek, where it is overlapped by the Itchegoin group and San Benito gravels. The thickness is comparaively uniform, varying but little from 200 feet. The sandstone is esistant to erosion, and characteristically forms a narrow topographic idge, with troughs or saddles on either side. It is covered by oaks and rass like the overlying Kreyenhagen shale, but usually the concentraion of oaks is greater than on the shale.

The Domengine is typically a fine- to medium-grained wellemented calcareous sandstone, gray to whitish on fresh exposure, but veathering yellowish brown. It may be massive, or bedded in layers to 3 feet thick. In general it seems finer-grained, more calcareous, nd less quartzose than the underlying Yokut sandstone. Three minral analyses reveal a variety of heavy minerals. These include glaucohane, zircon, hypersthene, magnetite, garnet, biotite, chlorite, augite, rown tourmaline, rutile, and sphene. This assemblage, particularly he glaucophane, is indicative of a Franciscan source at least in part.

At the base of the Domengine is one of the most important unconormities in the Butts Ranch synclinal section. This is shown not so nuch by a difference in dip with the underlying formations, which annot be readily determined, but by its profound overlapping onto trata of different ages. On the south side of the syncline the Domenine rests upon the Yokut sandstone, the next oldest formation. But n the north side of the syncline it rests alternately upon the Butts Ranch shale and the Call sandstone members of the Panoche group. On the same limb of the syncline, farther east in Moody Gulch it gain lies upon the Yokut. The Domengine shows similar overlapping elations at various places along the west side of the San Joaquin alley.

The Domengine sandstone is abundantly fossiliferous, although he forms are usually poorly preserved. The fauna so far collected is

exclusively molluscan, divided about equally between pelecypods and gastropods, except for one coral, a *Turbinolia.* The most diagnostic as well as most abundant fossil is *Turritella buwaldana,* which was found at nearly every locality. This is taken to be characteristic of the Domengine, middle Eocene.

The fauna, identified by H. G. Schenck and the writer, is indicated in the following list:

ANTHOZOA
Turbinolia sp.

PELECYPODA
Crassatella uvasana (Conrad) semidentata ? (Cooper)
Crassatella ? sp.
Glycymeris sp.
Macrocallista sp.
Miltha (Eomiltha) packi ? (Dickerson)
Nemocardium linteum (Conrad)
Nemocardium cf. marysvillense (Dickerson)
Nuculana chaneyi ? Vokes
Nuculana gabbii (Gabb)
Nuculana sp.
Ostrea ? sp.
Pitar avenalensis ? Vokes
Pitar joaquinensis Vokes
Pitar sp.
Plagiocardium (Schedocardia) brewerii ? (Gabb)
Plagiocardium (Schedocardia) sp.
Solen domengenicus ? Vokes
Solen sp.
Trachycardium ? sp.
Venericardia sp.

GASTROPODA
Amaurellina caleocia Vokes
Conus hornii Gabb umpquaensis Hendon
Conus sp.
Cylichnina tantilla ? (Anderson and Hanna)
Cylichnina sp.
Domenginella ? sp.
Ficopsis remondii (Gabb) crescentensis Weaver and Palmer
Molopophorus ? sp.
Pachycrommium clarki ? (Stewart)
Pachycrommium ? sp.
Polinices hornii (Gabb)
Rimella (Macilentos) macilenta White
Scaphander (Mirascapha) costatus (Gabb)
Surculites matthewsonii ? (Gabb)
Turritella buwaldana Dickerson

Kreyenhagen Shale (Upper Eocene)

The Kreyenhagen shale (Anderson 05, pp. 163-168) is a group foraminiferal calcareous, siliceous, and clay-shales, with some inte bedded sandstone and limestone, which occurs on both limbs of t Butts Ranch syncline. The northeast limb has a thickness of 400 1800 feet, the southwest limb 1500 to 2500 feet. The shale is le resistant to erosion than the adjacent formations, although the ind vidual members vary in this respect. It supports oaks and grass southerly slopes, and brush of the scrub-oak type on northerly slop The latter grows most profusely on platy siliceous shales in the upp part of the section.

The Kreyenhagen shale in this area rests everywhere upon t Domengine sandstone with apparent conformity. The nearly consta thickness of the relatively thin Domengine sandstone horizon over broad area seems good evidence for the absence of any appreciab erosional interval prior to deposition of the Kreyenhagen.

The most complete section of the Kreyenhagen, on the southwest ide of the Butts Ranch syncline, shows the following units:

	Thickness (feet)
Upper member. Siliceous and calcareous foraminiferal platy shales, with some limestone	500–1500
Bear Canyon sandstone member. Buff to brownish massive sandstone	100– 300
Foraminiferal clay-shales and platy shales, with some interbedded sandstone and limestone, and a thin glauconitic sandstone at the base. Equivalent to Canoas siltstone member of Coalinga district	300–1000

The only unit which was mapped separately is the Bear Canyon andstone member. This member does not occur on the northeast side f the syncline, and here no sharp division between units 1 and 3 was ound, hence the latter were not distinguished on the map as carto- raphic units.

anoas Member

The lower third of the Kreyenhagen on both sides of the Butts anch syncline is faunally equivalent to the Canoas siltstone member f the Coalinga district (Cushman and Siegfus 42, pp. 390-391).

The base is usually marked by a thin glauconitic sandstone layer anging from a few feet to 50 feet thick. In places this rock contains nore than 50 percent glauconite.

The rest of the member consists of foraminiferal gray to brown lay-shales and some platy calcareous and siliceous shales. Occasional ellowish limestones and buff to brownish poorly indurated sandstones re interbedded with the shales.

ear Canyon Sandstone Member

The term Bear Canyon sandstone member is proposed for a per- istent sandstone occurring about one-third of the distance above the ase of the Kreyenhagen on the southwest side of the Butts Ranch syncline. The type locality is designated as Bear Canyon, 1 mile north of Big Oak Flat. The sandstone has a thickness of 100 to 300 feet. It is fine- to medium-grained, micaceous, gray on fresh exposure, but weathering buff to brownish; moderately to well indurated. No fossils were found in the sandstone. It is more resistant to erosion than the adjacent shales, and supports a somewhat denser growth of oak trees, by which it may be followed over part of its course on the aerial photographs.

Upper Member

The upper two-thirds of the Kreyenhagen shale consists of platy siliceous and calcareous shales, containing abundant Foraminifera and Radiolaria; and some interbedded clay-shales. The platy shales commonly weather white, but appear chocolate brown on fresh exposures. Some of them are fairly resistant to erosion. Toward the lower part of this member are some yellowish-weathering limestones, in beds 2 to 3 feet thick.

Fossils, Correlation, and Age

Foraminifera are abundant at various horizons in the Kreyenhagen shale. The following collection was made from the Canoas member on the southwest side of the Butts Ranch syncline:

Anomalina crassisepta Cushman and Siegfus
Anomalina garzaensis Cushman and Siegfus
Asterigerina crassaformis Cushman and Siegfus
Bulimina n. sp.
Cibicides n. sp.
Cibicides pygmaeus (Hantken)
Cibicides venezuelanus Nuttall
Dorothia eocenica Cushman
Eponides sp.
Eponides minimus Cushman
Marginulina asperuliformis (Nuttall)
Marginulina subbullata Hantken
Plectina garzaensis Cushman and Siegfus
Pleurostomella nuttalli Cushman and Siegfus
Pullenia eocenica Cushman and Siegfus
Robulus welchi Church
Silicosigmoilina californica Cushman and Church
Tritaxilina pupa (Gümbel) of Cushman
Vulvulina curta Cushman and Siegfus

H. G. Schenck states that this assemblage is equivalent to the Canoas member of the Kreyenhagen, or to the A-2 zone of Laiming (40, pp. 544-545).

A less distinctive assemblage from the northeast side of the syncline, 50 feet above the base, was identified as follows:

Cyclammina sp.
Haplophragmoides eggeri Cushman
Silicosigmoilina californica Cushman and Church

The upper part of the Kreyenhagen shale contains a different foraminiferal assemblage. The following were collected about 400 feet above the base, on the northeast side of the Butts Ranch syncline:

Amphimorphina sp.
Anomalina cf. dorri Cole
Asterigerina cf. crassaformis Cushman and Siegfus
Bathysiphon eocenica Cushman and Hanna
Bulimina corrugata Cushman and Siegfus
Cibicides venezuelanus Nuttall
Cibicides sp.
Cyclammina sp.
Dentalina sp.
Dorothia principensis Cushman and Bermudez
Dorothia sp.
Eponides cf. umbonatus (Reuss) of Cushman
Eponides sp. 1
Eponides sp. 2
Glandulina sp.
Gyroidina sp.
Gyroidina octocamerata Cushman and Hanna
Lenticulina sp.
Nodogenerina sp.
Nodosarella sp. 1
Nodosarella ? sp. 2
Nodosaria arundinea Schwager of Cushman and Hanna
Nodosaria consobrina d'Orbigny of Cushman and Hanna
Nodosaria sp. 1
Nodosaria sp. 2
Plectofrondicularia aff. cookei Cushman
Pleurostomella sp.
Pulvinulinella tenuicarinata Cushman and Siegfus
Robulus sp. 1
Robulus sp. 2
Robulus sp. 3
Robulus sp. 4
Robulus sp. 5
Spiroplectammina ? sp.
Spiroplectoides californica Cushman and Campbell
Uvigerina garzaensis Cushman and Siegfus
Virgulina sp.
Vulvulina curta Cushman and Siegfus

H. G. Schenck, who examined the slide containing these Foraminifera, states: "I feel fairly certain that your faunule is younger than those commonly referred to as 'Canoas.' The assemblage is thus younger than the basal Kreyenhagen north of Coalinga, but older than the upper Kreyenhagen or Tumey sandstone and shale of the same district." [5]

Temblor Group (Middle Miocene)

The Temblor group (Anderson 05, pp. 168-187) is represented in the San Benito quadrangle by three mappable units: a lower sandstone, 100 to 500 feet thick; a shale in the middle of the section, 300 to 1000 feet thick; and an upper sandstone, 400 feet thick. They are exposed along the axis of the Butts Ranch syncline, and are the youngest rocks affected by the folding of the syncline. The three members are conformable with one another. The lower member rests disconformably upon the Kreyenhagen shale, judging from the following evidence:

1) The great variation in thickness of the underlying Kreyenhagen shale and its apparent overlap by the Temblor in some places. For example, in the extreme northwest part of the syncline all but 400 feet of the Kreyenhagen is overlapped.

2) The absence of true Vaqueros ("lower Miocene") deposits in the area.

No significant difference in attitude between the two formations could be measured, but little reliance was placed on determinations in the easily slumped shales of the Kreyenhagen.

The Temblor sandstones are more resistant to erosion than the middle shale, and form slight topographic ridges separated by a comparatively low, gently rounded belt. The shale supports oaks and grass on southerly slopes, dense brush of the scrub-oak type on northerly slopes, and chaparral (chamise and manzanita) on some of the southerly slopes.

Temblor Lower Sandstone

The Temblor lower sandstone consists chiefly of gray, buff, or brownish poorly cemented sandstones, which are occasionally fossiliferous, and a well-cemented calcareous gray fossiliferous "reef" bed at the top of the section. This "reef" bed, which occurs immediately below the Temblor shale, is a distinctive lithologic unit. It was traced for at least $3\frac{1}{2}$ miles along the southwest side of the syncline, and was also found for a short distance on the northeast side. The "reef" bed is packed with Pseudocardiums and an undescribed species of *Chlamys*, and contains occasional gastropods.

The sandstones lying below the "reef" bed are poorly sorted, fine- to coarse-grained, consisting of subangular grains of quartz, feldspars, rock fragments, biotite, and other ferromagnesians. Heavy minerals present include epidote, garnet, magnetite, rutile, tourmaline, and zircon. Bedding is poorly shown. Occasional pebbly beds occur, containing small pebbles $\frac{1}{4}$- to $\frac{1}{2}$-inch in diameter of chiefly Franciscan debris, including sandstone, chert, and glaucophane schist. The pre-Franciscan porphyries, black cherts, and quartzites are also present.

[5] Letter dated April 10, 1940.

Poorly preserved mollusks occur sparsely at various places in the Temblor lower sandstone, but are abundant in the "reef" bed at the top. *Mytilus expansus* and *Pseudocardium* sp. are the most abundant fossils. A small, many-ribbed *Chlamys* is common in the "reef" bed, but it belongs to an undescribed species, according to B. L. Clark, L. G. Hertlein, and H. G. Schenck, all of whom have examined it. The most distinctive forms are *Bruclarkia oregonense* and *Turritella inezana* var. L. G. Hertlein, who examined the faunule, believes that it is equivalent to the "Vaqueros-Temblor transition stage" of Loel and Corey (32), or "lower-middle Miocene."

The fossils in the following list were determined by L. G. Hertlein, H. G. Schenck, and the writer.

ANTHOZOA

Undetermined

PELECYPODA

Antigona sp.
Chlamys n. sp.
Clementia ? sp.
Crassatellites ? sp.
Glycymeris aff. branneri Arnold
Glycymeris sp.
Lucina ? sp.
Mytilus expansus Arnold
Ostrea titan (Conrad) subtitan ? Loel and Corey
Pachydesma sp.
Panope estrellana Conrad
Pseudocardium sp.
Solen gravidus ? Clark
Spisula abbotti ? Wiedey
Tellina sp.

GASTROPODA

Bruclarkia oregonense (Conrad)
Calyptraea costellata (Conrad)
Polinices ? sp.
Thais ? sp.
Tritonalia ? sp.
Turritella inezana (Conrad) var.

CIRRIPEDIA

Balanus sp.

MISCELLANEOUS

Teredo borings in wood

Temblor Shale

The Temblor shale consists of hard platy siliceous and calcareous foraminiferal shales, and a few clay-shale partings. The platy shales are chocolate brown on fresh exposure, but weather white. They sometimes show a rhythmic banding, in addition to a well-developed bedding in layers 2 to 3 or sometimes 6 to 8 inches thick. A few fine-grained sandstone and sandy shale layers are interbedded with the platy shales.

Foraminifera are fairly abundant in the Temblor shale, but because of its hard siliceous nature determinable specimens could not be washed out. Determinations in the unwashed shale were made by H. G. Schenck as follows:

Bathysiphon ? sp.
Dentalina sp.
Plectofrondicularia sp.
Plectofrondicularia miocenica ?
Uvigerina ? sp.

The shale contains, besides Foraminifera, abundant fish scales and a few mud pectens. The latter were determined by H. G. Schenck as *Delectopecten* aff. *peckhami* (Gabb).

Although none of these fossils are sufficiently distinctive for an age determination, the position of the shale between the Temblor lower sandstone and upper sandstone establishes its age as Temblor (middle Miocene). The fossils are not incompatible with this determination.

Temblor Upper Sandstone

The Temblor upper sandstone consists of massive, friable, gray to yellowish sandstones and occasional intercalated shale layers. The sandstone is poorly sorted, medium- to coarse-grained, consisting of angular to subangular grains of feldspars, quartz, biotite, other ferromagnesians, and numerous rock fragments. A few pebbly layers occur, containing chiefly Franciscan pebbles, and a few of the pre-Franciscan group.

Mineral analysis reveals a great variety of heavy minerals, including such comparatively unusual varieties as andalusite and idocrase. In greatest abundance are green hornblende, brown biotite, and augite; there are smaller amounts of green biotite, magnetite, zircon, garnet, epidote, glaucophane, muscovite, and sphene. Volcanic glass is rare; when present, it has a refractive index of $1.506 \pm .004$, indicating a silica content of about 70 percent (George 24).

Mollusks are scarce and usually poorly preserved in the Temblor upper sandstone. The common forms are similar to those occurring in the Temblor lower sandstone, exclusive of the "reef" bed. Perhaps the most diagnostic species is *Bruclarkia oregonense.*

The best evidence for the Temblor age occurs along the easterly extension of the formation in the Panoche quadrangle, where Mielenz (39, p. 167) found specimens of *Echinarachnius merriami* (F. M. Anderson). This occurs with *Turritella ocoyana* Conrad in the northeastern end of the Vallecitos (Anderson and Pack 15, p. 86). Both species are believed to be good markers of the Temblor formation.

The following species were determined in the Temblor upper sandstone:

PELECYPODA

Mytilus expansus Arnold
Ostrea sp. (large)
Pachydesma gabbi (Clark)
Panope estrellana (Conrad)
Solen sp.
Tagelus sp.

GASTROPODA

Bruclarkia oregonense (Conrad)
Calyptraea costellata (Conrad)
Olivella ? sp.
Polinices ? sp.

Miocene Volcanics

A great series of Miocene rhyolite flows, dikes, and pyroclastics, and a few more basic flows, is located in the Gabilan Range in the southern part of the San Benito quadrangle. The main volcanic area lies in the Pinnacles National Monument, extending north about a mile into the San Benito quadrangle. Another center of eruption lies farther north in the Willow Creek region, and smaller patches of volcanics

are exposed between these areas. Miocene volcanics are widespread in the Coast Ranges, but this is perhaps the largest area in which rhyolite is the dominant rock, and the largest area of subaerial explosive eruptions.

Rhyolite flows were erupted first, and were followed in places by more basic flows in small quantities. Then came a series of great explosive eruptions which produced thick deposits of rhyolite breccia, tuff, and agglomerate, called the Pinnacles formation (Andrews 36). These were followed near the north end of the Pinacles National Monument by another smaller flow of rhyolite. The volcanics have the following thicknesses in the San Benito quadrangle:

	N. end of Pinnacles	*Willow Creek area*
Upper rhyolite flows	700	----
Pinnacles formation (volcanic breccia)	2600	700–1000
Lower rhyolite flows	1000	700

Rhyolite Flows

The rhyolites are generally white or gray, occasionally pink, lavender, or green. They show marked flow-banding, which is often strongly contorted and wrinkled. They have a small number of phenocrysts, only an occasional flake of biotite or grain of quartz being distinguishable with a lens. Microscopically they are seen to be very finely porphyritic, containing occasional small crystals of quartz, untwinned feldspar (sanidine and albite), brown biotite, apatite, magnetite, and zircon. The groundmass is aphanitic to glassy, showing a mass of microspherulites and a "pepper and salt" aggregate of fine-grained quartz and untwinned feldspar. The microspherulites, sometimes brownish in color, average 0.1 to 0.2 mm in diameter, and show negative elongation of the fibers. Masses of volcanic glass, usually partially devitrified, occur with the rhyolite.

The rhyolite is resistant and forms bold, projecting outcrops. A prominent feature of the landscape is Willow Creek Peak, a saddle-shaped mountain of rhyolite dipping steeply toward the west, with a cliff and talus slope on the eastern face. The rhyolite is covered by low brush of the sagebrush type or by chaparral.

Columnar joining is well developed southwest of Willow Creek Peak. The joints lie at right angles to flow-banding tilted 80° to the west. The columns are five- and six-sided, have an average diameter of 1 to 2 feet, and a length of 6 feet. Jointing elsewhere in the rhyolite has aided in formation of many cliffs.

Basic Flows

Some basic flows are exposed above the rhyolite, immediately below the Pinnacles formation, on Chalone Creek. These are colored dark red to black. A specimen of one of these flows, examined under the microscope, proved to be a quartz basalt containing xenocrysts of quartz and plagioclase up to 2 mm in diameter, probably derived from the underlying granite. The quartz xenocrysts are surrounded by reaction rims of chlorite. The major part of the rock is microcrystalline, subtrachytoid, consisting of plagioclase ($Ab_{50}An_{50}$), augite, brown biotite,

hypersthene (partially altered to serpentine and hematite), magnetite, ilmenite, and zircon.

Small flows of dense black basalt occur intercalated with the Pinnacles formation on Willow Creek, in sec. 30, T. 15 S., R. 7 E., M. D.

Rhyolite Dikes

Numerous rhyolite dikes cut the Santa Lucia granite in the southwestern part of the quadrangle, west of the Pinnacles fault and south of Bickmore Canyon. They range in width from a few feet up to 600 feet, averaging 100 or 200 feet, and range in length from a few tens of feet up to 2 miles. They are intruded in a definite pattern along fractures which have an average strike of N. 30° W., and dip of 55° to 65° NE. Very few dikes have a trend differing from this. Some of the fractures have en echelon relationships.

The rhyolite in the dikes differs from that of the flows in that it generally lacks flow-banding and is more noticeably porphyritic. Small phenocrysts of quartz, orthoclase, and biotite may generally be seen with a lens. The groundmass is aphanitic to microcrystalline, made up largely of an aggregate of quartz and orthoclase, with subordinate oligoclase, biotite, muscovite, and magnetite. In some of the larger dikes the rock is very coarsely porphyritic. The central part of a 600-foot-thick dike on Chalone Creek contains phenocrysts of orthoclase up to an inch in diameter and quartz $\frac{1}{4}$-inch in diameter. This, however, is an unusual occurrence. Some of the dikes have a composition closer to that of dacite than rhyolite. These are colored dark gray and have phenocrysts of quartz, plagioclase, and biotite. A few more basic dikes, possibly of andesitic composition, were also seen.

The dikes commonly have a marked system of joints parallel with the fractures along which they were intruded, and one or more sets at right angles thereto. More resistant than the adjacent granite, they stand up as prominent ridges. They support a growth of chaparral or low brush of the sagebrush type.

Pinnacles Formation

The Pinnacles formation is a thick sequence of rhyolitic pyroclastic deposits, chiefly volcanic breccia, with some tuff and agglomerate. It was named by Andrews (36, p. 19) for exposures in the Pinnacles National Monument, where it reaches a thickness of 2600 feet. A separate belt 700 to 1000 feet thick occurs in the Willow Creek area, extending northwest for a distance of 5 miles. Smaller faulted blocks of the breccia are exposed on either side of Bear Valley.

The formation is coarsely stratified, and consists almost entirely of angular fragments of rhyolite, both flow-banded and massive, averaging 1 to 3 inches in diameter, in a tuffaceous matrix. Microscopically the matrix is seen to be composed of finely comminuted rhyolite fragments, with fewer fragments of quartz, untwinned feldspar, and glass, some of which is devitrified. The matrix sometimes reveals microspherulites.

The deposits show considerable variation. The fragments range in size from ash up to blocks 6 feet or more in diameter. Some of the beds containing larger fragments could be called agglomerate. There are also some beds of lapilli-tuff and tuff-breccia. The fragments are

ordinarily angular, but in a few places some rounding is seen. At one locality on Willow Creek spindle-shaped vesicular bombs 8 inches in diameter occur in a tuffaceous matrix.

The only nonvolcanic fragments are some derived from the underlying granite. These are not scattered uniformly through the formation but are concentrated in single beds. One such bed containing abundant angular to subangular fragments of granite 4 to 6 inches in diameter occurs near the top of the formation at the north end of the Pinnacles National Monument. Where the formation rests directly on granite in the Willow Creek area fragments of granite are common in the basal portion. Some of these are boulders 5 or 6 feet in diameter, and in places it appears that the volcanic material was deposited on a residual breccia formed on the granite surface. However, in much of the formation granite fragments are entirely absent.

The Pinnacles formation is strongly jointed. Weathering and erosion along vertical joints have produced the many spires, crags, and steep cliffs which provide the scenic beauty and the name for the Pinnacles National Monument. In some places the joints have been enlarged into crevices, which have later been partially covered by large blocks tumbled from the cliffs on either side, to form caves. The formation supports a sparse growth of vegetation, mainly low brush of the sagebrush type or scattered chamise, and occasional pines.

The origin of the Pinnacles formation hinges upon the following characteristics: (1) the fragments are not waterworn; this eliminates the possibility of breccias resulting from transportation by water; (2) the fragments are chiefly of flow-banded or massive non-vesicular rhyolite; hence they must have been nearly solid before they were blown out; this eliminates the péléan type of eruption; (3) the material shows some stratification.

The type of volcanic eruption to which these characteristics seem most applicable is the vulcanian type. This is the opinion of Howel Williams, who examined the formation in the Willow Creek area in company with the writer. Periods of quiescence between eruptions produced stratification of the deposits.[6]

Some variation from this type of eruption is evidenced by the small deposit observed on Willow Creek in which spindle-shaped vesicular bombs occur in a tuffaceous matrix. This occurrence seems to be exceptional.

Andrews (36, p. 26) believed that the dips of the breccia, averaging about 35° but often reaching 50° or more, were largely initial. The writer does not concur in this, because Monterey shales and sandstones overlie the breccias in many places with no difference in strike or dip, and sediments of this nature could not be deposited with such a high initial dip. The present dip is evidently due to tilting long after the breccias were deposited.

Vent Tuff

Andrews (36, p. 24) recognized at least five vents in the Pinnacles area, characterized by "more or less circular masses of volcanic tuff within non-fragmental rhyolite." Another area of tuff marking a

[6] Williams, Howel, personal communication, 1940.

possible vent occurs half a mile east of Willow Creek Peak. This is a roughly oval-shaped area, a quarter of a mile in diameter, of decomposed white ash and lapilli-tuff, surrounded by and cut in a few places by rhyolite. The tuff on the periphery dips toward the center of the vent. The tuff is highly altered, sericitized and opalized, in places stained by hematite, indicating fumarolic action.

Several thin-sections of tuff and tuff-breccia from the Willow Creek Peak vent were examined. These contain angular lithic rhyolitic fragments in a fine-grained tuffaceous matrix. The lithic fragments are yellowish in color, and have been highly altered to a mixture of opal and sericite. They are largely glassy, partially devitrified, showing an occasional "salt and pepper" structure as well as microspherulites. The matrix of the tuff-breccia consists of irregular fragments of very fine-grained quartz and untwinned feldspar and partially devitrified glass. Microspherulitic structures occur in the matrix, often arranged along fractures. The microspherulites are 0.05 to 0.1 mm in diameter, have a refractive index below Canada balsam, and exhibit a uniaxial negative cross under crossed nicols.

The vent tuff is easily eroded and forms a low bench or basin-like area on the flank of Willow Creek Peak. The more resistant rhyolite surrounding the tuff forms a rim around part of the basin. The tuff is covered by a dense growth of chaparral (chamise and manzanita).

Age of the Volcanic Activity

The age of the Pinnacles formation and related volcanics has not been definitely determined, although there is little doubt that it is Miocene. The volcanics are overlain by a series of sediments correlated, largely on the basis of diatoms, with the Monterey group (upper Miocene). The volcanics are no younger than upper Miocene, therefore. However, the basal shale overlying the Pinnacles formation on Willow Creek may be of Temblor (middle Miocene) age, so that the volcanics could be middle Miocene or older.

There is no certain way of obtaining a lower limit of age of the volcanics, since they rest directly on granite. An indirect line of evidence is the occurrence of volcanics on the north flank of the Gabilan Range 30 miles northwest of the Pinnacles in the San Juan Bautista quadrangle. These are described by Kerr and Schenck (25, p. 473) as consisting of rhyolite, andesite, basalt, and agglomerate, and they overlie the Vaqueros sandstone (lower Miocene). If these volcanics are equivalent to those of the Pinnacles region, it would place a lower limit of Vaqueros as the age of the Pinnacles volcanics.

Herold (37) believes that the volcanic activity at the Pinnacles continued into the latest Miocene and possibly earliest Pliocene, on the basis of vitric tuffs found in the Salinas and Jamesburg quadrangles, whose source he thinks was in the Pinnacles area. Although a late Miocene age for some of the activity might be possible, it does not seem probable to the writer, and the great thickness of Miocene sediments overlying the volcanics would seem to exclude the possibility of a Pliocene age.

We may conclude that the Pinnacles volcanic activity is of Miocene age, most likely middle Miocene.

Basic Volcanics in Diablo Range

Three small, isolated areas of basic volcanics, chiefly basalt, occur in the Diablo Range in the San Benito quadrangle. These cannot be correlated with the volcanic activity at the Pinnacles. The occurrences are located: (1) half a mile south of Pine Rock, west of San Benito River, in the Santa Margarita formation; (2) on the east bank of Salt Creek, near center of Butts Ranch syncline, in the Temblor shale; and (3) on Chemise Ridge, north flank of Call Mountains, in the Paynes shale and sandstone member of the Panoche group.

The last two occurrences are probably intrusive, hence of uncertain age; but the first is a flow intercalated with the sediments of the Santa Margarita formation, and thus is upper Miocene. This Santa Margarita flow has a maximum thickness of 200 feet, and is exposed for nearly three-quarters of a mile. The lower contact with the Santa Margarita sediments is well exposed in one place; here a fine-grained white sandstone is baked and colored reddish for a distance of 1 to 2 feet below the contact. The basalt is black, or greenish on fresh surface, and forms a reddish soil. It is amygdaloidal, the amygdules being calcite. The rock is also cut by small veinlets of calcite.

Examined microscopically, the basalt in the Santa Margarita formation is seen to be porphyritic, with an intersertal groundmass. The phenocrysts are of labradorite ($Ab_{40}An_{60}$) and occasional titaniferous augite. The groundmass consists of lath-shaped plagioclase, augite, magnetite, and occasional iddingsite derived from olivine. The feldspars show both albite and Carlsbad twinning, and often have a latticework of magnetite inclusions.

Monterey Group (Upper Miocene)

The Monterey group (Blake 56, pp. 328-331) is represented by a fairly thin basal shale member, overlain by a considerable thickness of arkosic sandstone and conglomerate, which is interbedded toward the top with diatomaceous shale. An interesting feature is the gradation of the marine diatomaceous shale into very coarse conglomerate, probably non-marine, toward the west. There is good evidence of a western shoreline of the Monterey sea in the Gabilan Range.

The Monterey group is confined to the Gabilan Range, southwest of the Bear Valley fault. The basal shale rests depositionally (either conformably or disconformably) upon the Pinnacles formation along Willow Creek. The arkose rests unconformably upon the Pinnacles formation and Miocene rhyolite in the southern part of the quadrangle, and upon granite in the northwestern part of the area.

The basal shale forms a belt of low, well-rounded grass-covered slopes, supporting scattered oak trees. The arkosic sandstone and conglomerate is moderately resistant to erosion, and supports a moderate to dense growth of sagebrush or chaparral (chamise and manzanita). The diatomaceous shale is slightly less resistant and supports less dense vegetation of the same type as the arkose.

Basal Shale

The basal shale of the Monterey group consists of platy calcareous and siliceous shale, interbedded with softer clay-shale. It is well bedded

in layers 1 to 3 inches thick. The shale weathers white but is chocolate brown upon fresh exposure. Some of it is banded and cherty. A few beds 1 or 2 feet thick of fine-grained well-cemented arkosic sandstone are interbedded with the shale in places. The member has a thickness of 450 to 1100 feet.

Arkosic Sandstone and Conglomerate

The greatest part of the Monterey group consists of arkosic sandstone and conglomerate, with a total thickness of 1500 to 3000 feet. The material shows rapid lateral and vertical variation. In general it is very poorly sorted, containing in a sandy matrix pebbles and boulders averaging a few inches but ranging up to 12 feet in diameter. The sand grains are chiefly angular, in part subangular, and only the larger boulders are subrounded. The sandstone is highly arkosic, consisting chiefly of fresh feldspar (mainly orthoclase), quartz, and biotite; and a small percentage of heavy accessories, including muscovite, zircon, sphene, garnet, epidote, magnetite, augite, diopside, enstatite, and hypersthene. The pebbles and boulders consist entirely of granite and rhyolite. The granitic debris is generally dominant, but there are certain layers in which rhyolitic material is concentrated. Parts of the arkose are fairly well cemented by calcium carbonate, but most of the material is poorly consolidated.

The abundance of granite and rhyolite debris indicates derivation of material from part of the Gabilan Range, which was probably an island during the upper Miocene. The poor sorting, rapid lateral and vertical variation, angularity of grain, and extreme coarseness of some of the arkose suggest non-marine deposition, probably of the fanglomerate type. The deposits become finer grained and grade into marine deposits to the east, indicated by the diatomaceous shales and by the occurrence in at least one locality of marine molluscan fossils in the arkose.

Diatomaceous Shale

Diatomaceous shales are interbedded with the arkosic sandstone and conglomerate near the top of the section. These are well bedded, punky, and have a brilliant white appearance both on weathered surfaces and fresh exposures. Under the microscope, diatoms are seen to be very abundant. At least two or three different members of diatomaceous shale are present, ranging in thickness from 100 to 200 feet.

The most interesting feature of the diatomaceous shales is their interbedding with and gradation into coarse arkosic sandstone and conglomerate toward the west. At the head of the north branch of Chalone Creek the relations of the shale to the arkose are well exposed. At one place is a continuous section of 800 feet of diatomaceous shale with only a few intervening layers of fine-grained arkosic sandstone. Toward the west more and more sandstone of coarser grain-size interfingers with and grades into the shale. Layers of shale may be followed into sandstone along the strike. The last canyon in which the shale is exposed shows a series of several tens of layers of diatomaceous shale, 2 to 3 feet thick, separated by bands of sandstone and conglomerate, 15 to 20 feet thick, much of it very coarse. In the next well-exposed canyon, a quarter of a mile west of where the shale disappears, only

poorly sorted sandstone and conglomerate is exposed, some of it containing boulders up to 12 feet in diameter. The relations described above are clearly shown on an aerial photograph.

This occurrence is of interest in that diatomaceous shales have often been thought to indicate comparatively clear, quiet water, with very little terrigenous material being supplied to the depositional basin. Such cannot have been the case in this instance.

Fossils, Correlation, and Age

Fossils are rare in the Monterey group in this area. Only one locality of megafossils was found, near the eastern end of the Bickmore Canyon road. Here a few molluscan molds and casts together with leaf imprints occur in a fine-grained, well-cemented, arkosic sandstone. The identifiable mollusks were determined by L. G. Hertlein as *Taras harfordi* (F. M. Anderson), which has a range from Temblor to Etchegoin. Other undetermined pelecypods and gastropods are present. The leaves were determined by Ralph W. Chaney as cf. *Quercus previrginiana* Berry and cf. *Persea pseudocarolinensis* Lesquereux. He states that both of these species occur in the Monterey flora west of Carmel.

Diatoms from the diatomaceous shales of this area were identified by Kerr and Schenck (25, p. 484) as *Coscinodiscus incretus* A. Schmidt. H. G. Schenck states that an abundance of diatoms of this type is characteristic of the Delmontian, uppermost stage of the Miocene.[7]

It is largely on the basis of the diatoms and lithologic nature of the shale that the diatomaceous shales and interbedded arkosic sediments are referred to the Monterey group. The leaves and mollusks are compatible with this correlation. The basal shale, on the other hand, apparently contains no diatoms or other fossils, and its correlation is largely a matter of conjecture. It could be Temblor as readily as Monterey, and in fact is lithologically similar to the Temblor shales west of the Salinas Valley and in the Butts Ranch syncline area. The conformable contact with the Monterey makes it seem improbable that the shale is any older than Temblor (middle Miocene).

Santa Margarita Formation (Upper Miocene)

The Santa Margarita formation (Fairbanks 04) consists mainly of fossiliferous grayish calcareous sandstone, containing "reef" beds and pebbly conglomeratic layers, and occasional interbedded clay-shales. It has a maximum thickness of more than 2000 feet. It is exposed only in a narrow belt along the southwest bank of the San Benito River in the southern part of the quadrangle. The northernmost exposure is along the great bend of the San Benito River just west of the mouth of Sulphur Creek. This narrow belt dips uniformly to the west below the basal red beds of the overlying Etchegoin group. On the east the Santa Margarita is in fault contact with the Etchegoin along the Pine Rock fault, and the base is nowhere exposed. However, in a continuation of this belt to the southeast in the Priest Valley quadrangle, the Santa Margarita rests unconformably upon the Franciscan, according to Mielenz (39, p. 174).

[7] Personal communication, 1941.

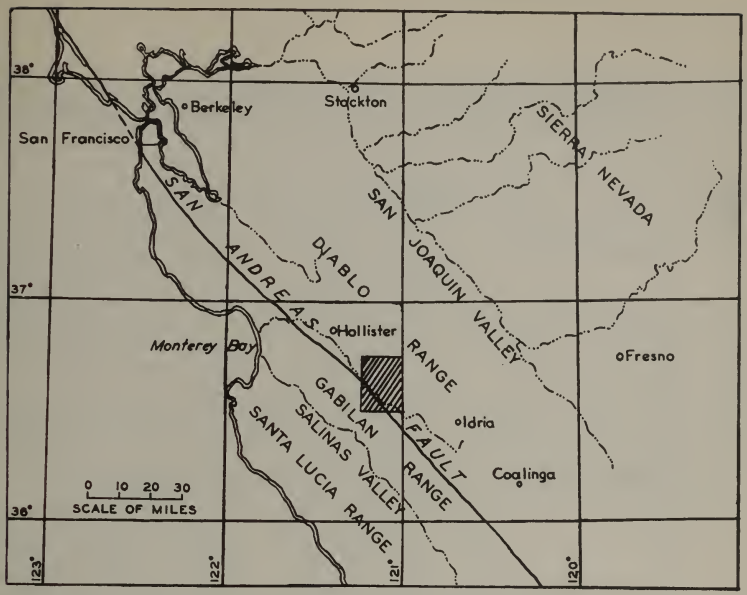


FIG. 1. Index map showing location of the San Benito quadrangle.

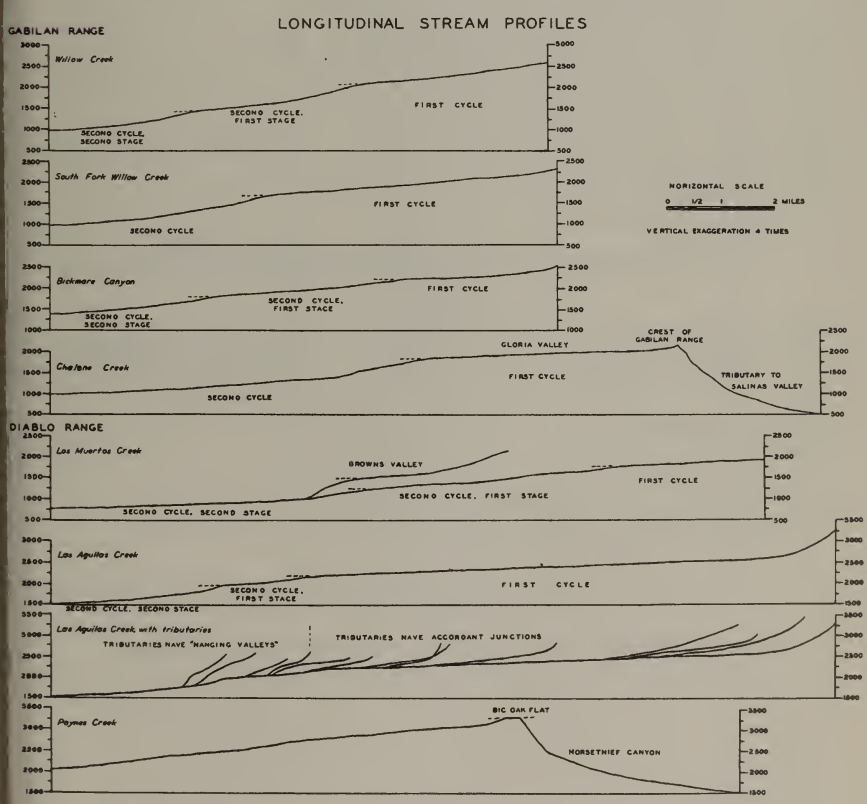


FIG. 2. Longitudinal stream profiles, showing two cycles of erosion.

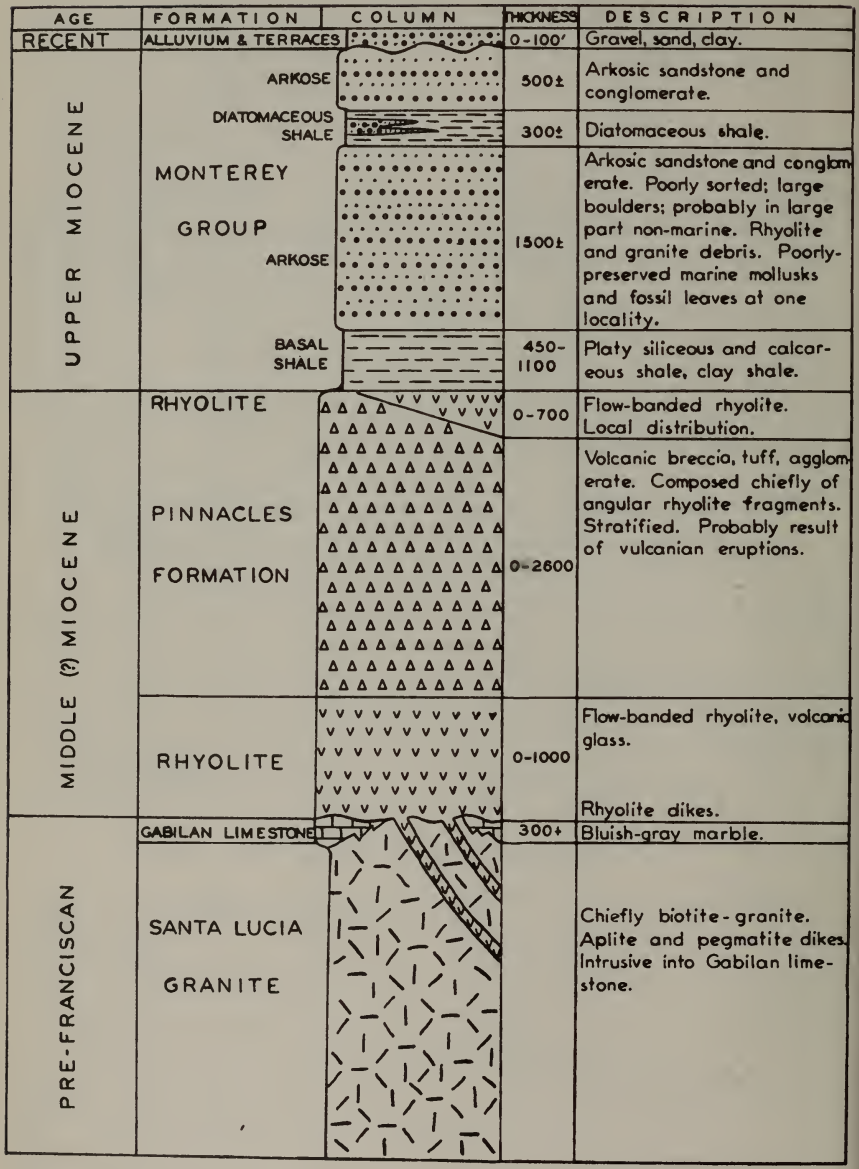


FIG. 3. Stratigraphic column, Gabilan Range, San Benito quadrangle.

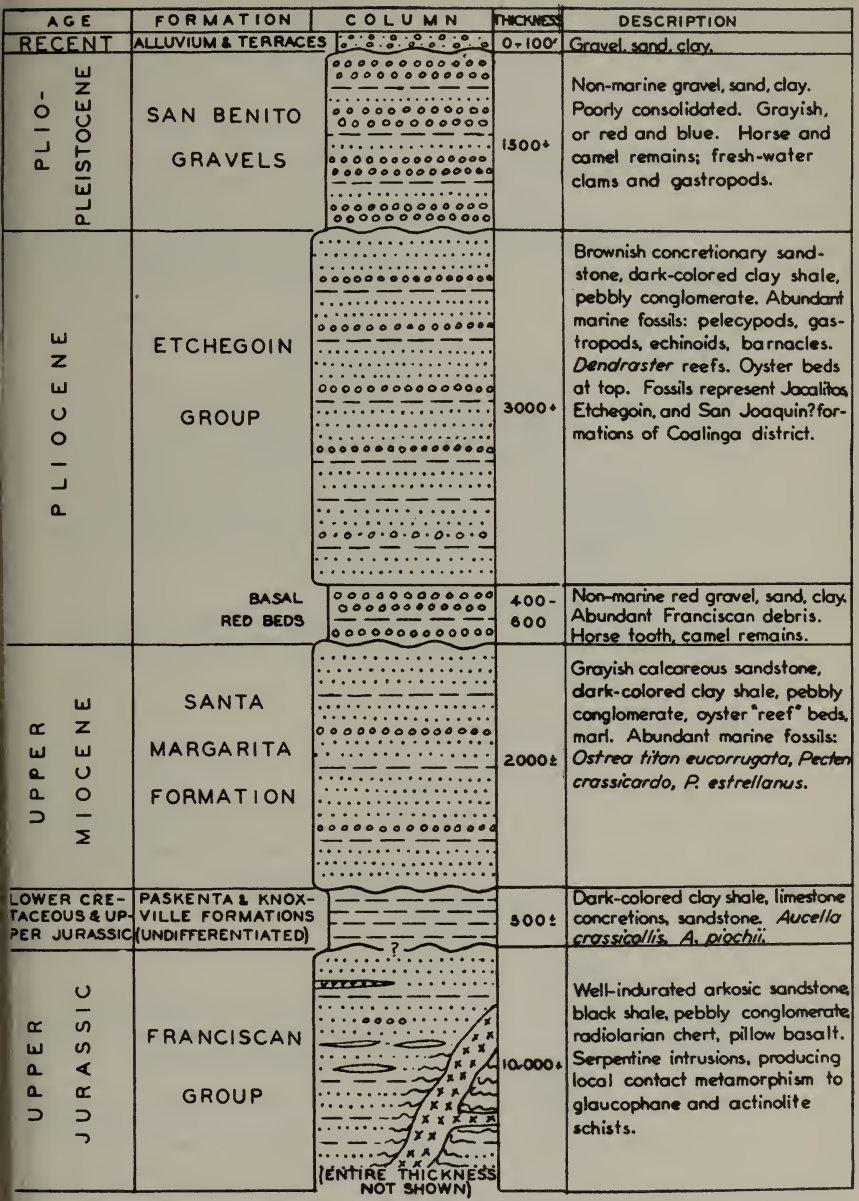

AGE
FORMATION
COLUMN
THICKNESS
DESCRIPTION
RECENT
ALLUVIUM & TERRACES
0+100'
Gravel, sand, clay.
PLIO-PLEISTOCENE
SAN BENITO GRAVELS
1500+
Non-marine gravel, sand, clay. Poorly consolidated. Grayish, or red and blue. Horse and camel remains; fresh-water clams and gastropods.
PLIOCENE
ETCHEGOIN GROUP
3000+
Brownish concretionary sandstone, dark-colored clay shale, pebbly conglomerate. Abundant marine fossils: pelecypods, gastropods, echinoids, barnacles. Dendraster reefs. Oyster beds at top. Fossils represent Jacalitos, Etchegoin, and San Joaquin? formations of Coalinga district.
BASAL RED BEDS
400-600
Non-marine red gravel, sand, clay. Abundant Franciscan debris. Horse tooth, camel remains.
UPPER MIOCENE
SANTA MARGARITA FORMATION
2000±
Grayish calcareous sandstone, dark-colored clay shale, pebbly conglomerate, oyster "reef" beds, marl. Abundant marine fossils: Ostrea titan eucorrugata, Pecten crassicardo, P. estrellanus.
LOWER CRETACEOUS & UPPER JURASSIC
PASKENTA & KNOXVILLE FORMATIONS (UNDIFFERENTIATED)
500±
Dark-colored clay shale, limestone concretions, sandstone. Aucella crassicollis, A. piochii.
UPPER JURASSIC
FRANCISCAN GROUP
10,000+
Well-indurated arkosic sandstone, black shale, pebbly conglomerate, radiolarian chert, pillow basalt. Serpentine intrusions, producing local contact metamorphism to glaucophane and actinolite schists.
(ENTIRE THICKNESS NOT SHOWN)

FIG. 4. Stratigraphic column, San Benito River area, San Benito quadrangle.

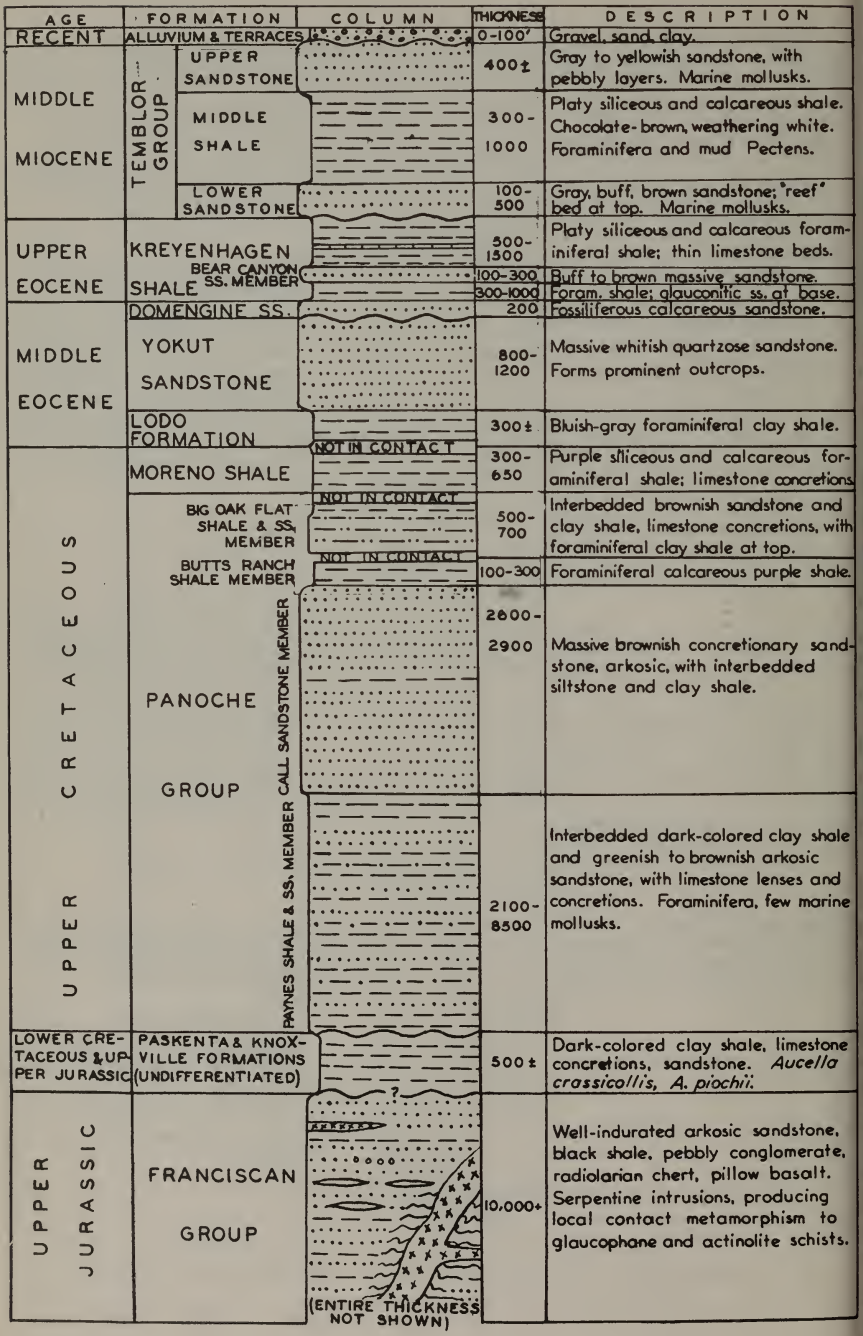


FIG. 5. Stratigraphic column, Butts Ranch syncline, San Benito quadrangle.

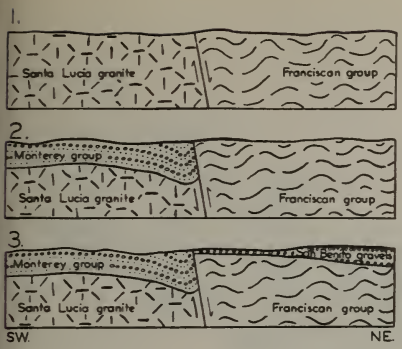


FIG. 6. Successive movements on the Bear Valley fault. 1. Pre-Miocene (probably Eocene): Franciscan upthrown and eroded off granite on southwest side. 2. Between upper Miocene and Pleistocene (probably upper Pliocene): Franciscan on northeast side thrust over Monterey. 3. Late Pleistocene or Recent: San Benito gravels downthrown on northeast side.

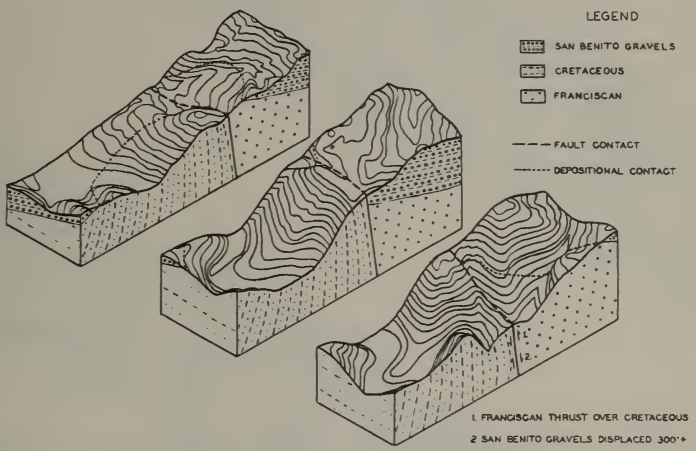


FIG. 7. Block diagrams showing reversal of movement along the Bradford fault.

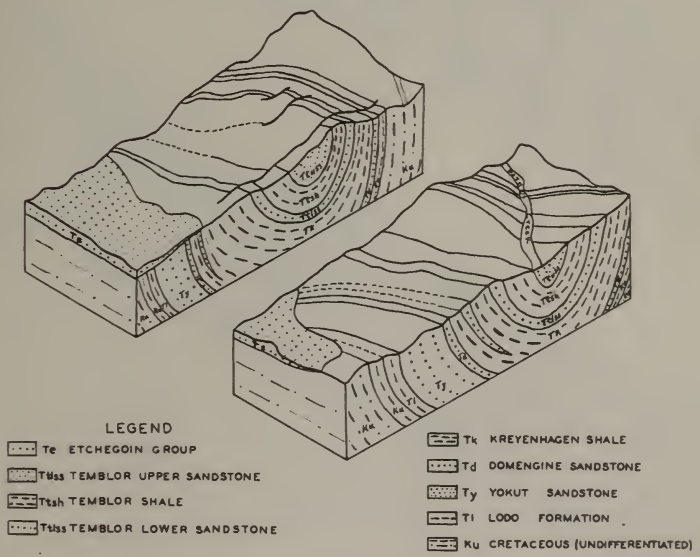


FIG. 8. Block diagrams showing overlap of Etchegoin sediments onto the Butts Ranch syncline.

FIG. 9. Block diagrams of the San Andreas and

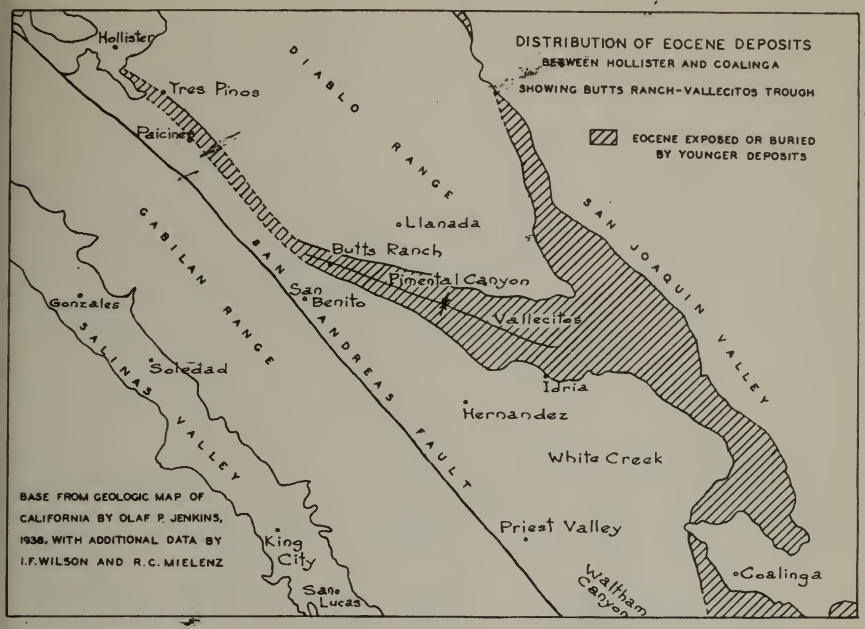


FIG. 10. Distribution of Eocene deposits between Hollister and Coalinga, showing Butts Ranch—Vallecitos trough.

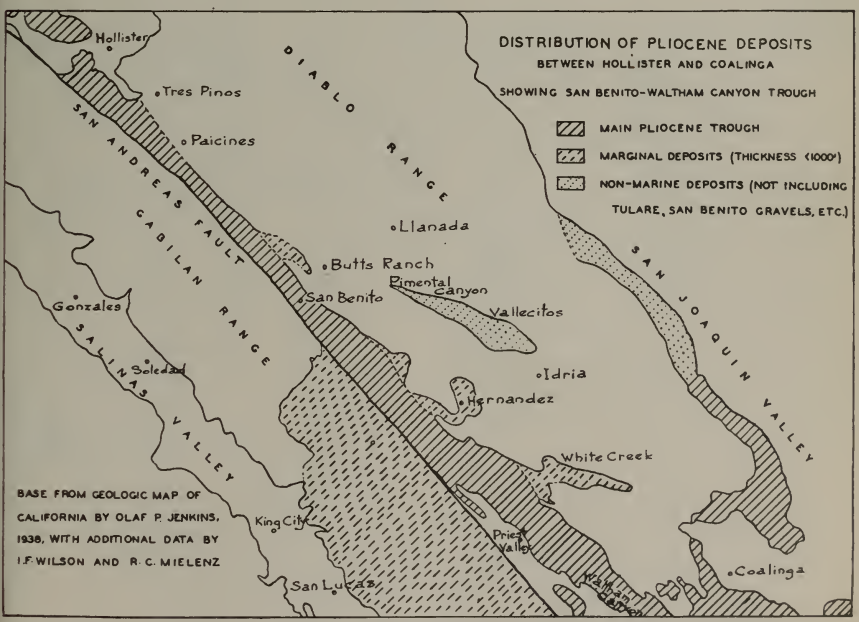


FIG. 11. Distribution of Pliocene deposits between Hollister and Coalinga, showing San Benito—Waltham Canyon trough.

GEOLOGIC STRUCTURE SECTIONS

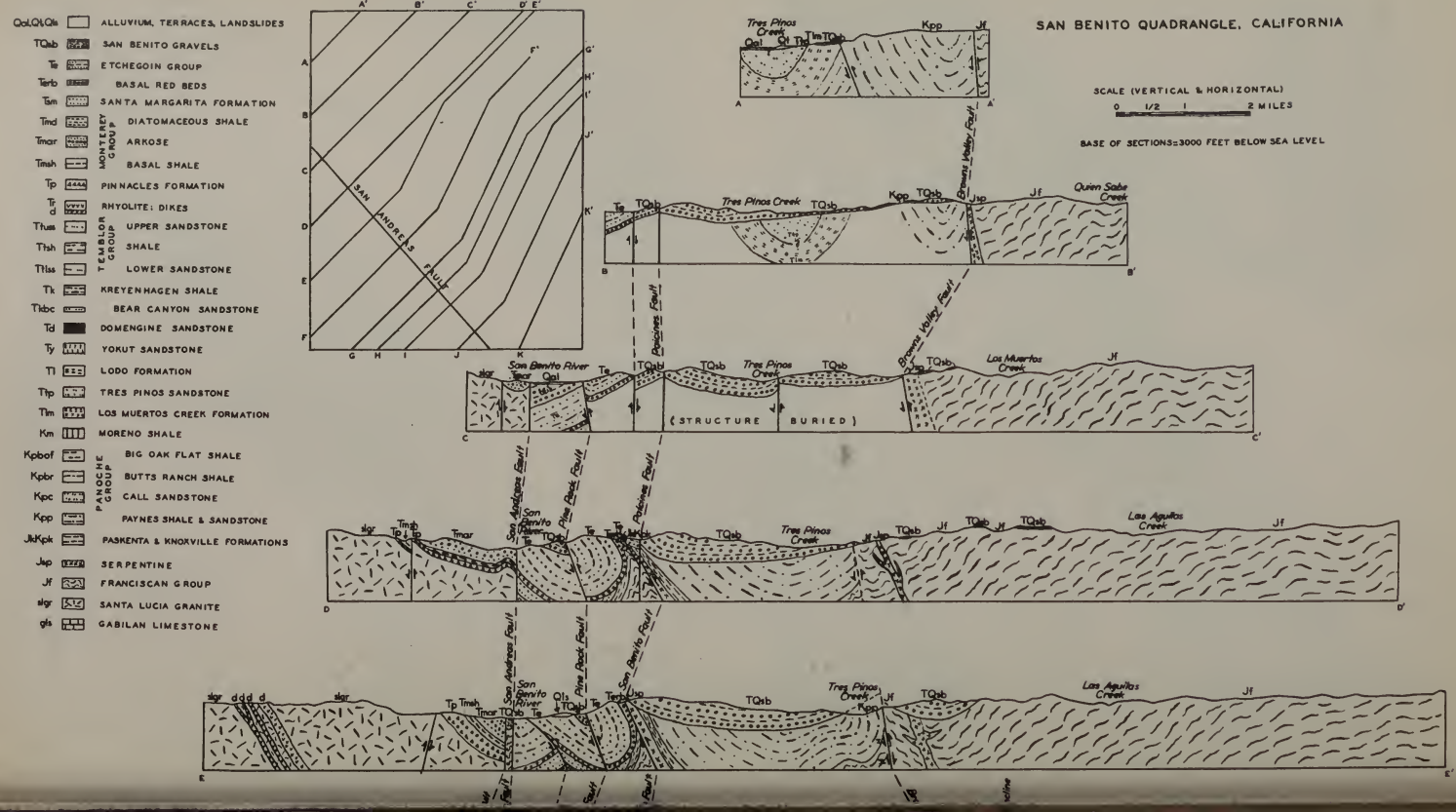
OF THE

SAN BENITO QUADRANGLE, CALIFORNIA

SCALE (VERTICAL & HORIZONTAL)

0 1/2 1 2 MILES

BASE OF SECTIONS=3000 FEET BELOW SEA LEVEL



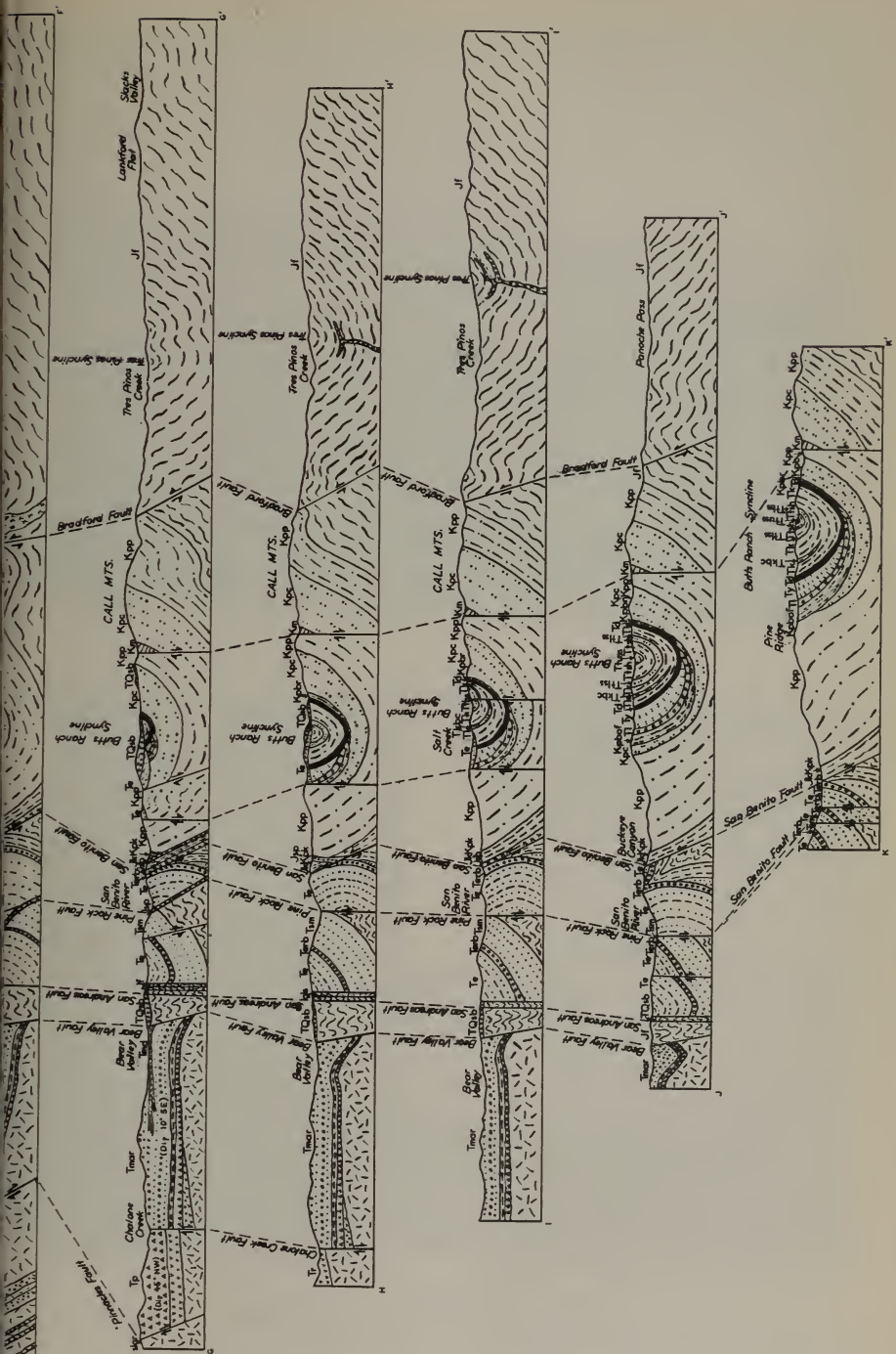

Bradford Fault
Bear Valley Fault
San Andreas Fault
Pine Rock Fault
San Benito Fault
Sag
Buttonwillow Fault
Chalone Creek Fault
Tres Pinos Creek
Tres Pinos Syncline
Pinnacle Pass
Buttonwillow Syncline
Pine Ridge Syncline
Butts Ranch Syncline
Soil Creek Syncline
CALL MTS.
Kpc
Kop
Kvk
Tsb
Tsc
Tsa
Tsm
Tmar
Tp
Tr
J
J1
Jsp
Jm
Jmk
Jmc
Jmp
Jmm
Jmt
Jmv
Jmw
Jmr
Jmb
Jmd
Jmg
Jmh
Jmi
Jmj
Jmn
Jmo
Jmq
Jmu
Jmx
Jmy
Jmz
Jmaa
Jmbb
Jmcc
Jmdd
Jmee
Jmff
Jmgg
Jmhh
Jmii
Jmjj
Jmkk
Jmll
Jmmm
Jmnn
Jmoo
Jmpp
Jmqq
Jmrr
Jmss
Jmtt
Jmuu
Jmvv
Jmww
Jmxx
Jmyy
Jmzz
Jmaaa
Jmbbb
Jmccc
Jmddd
Jmeee
Jmfff
Jmggg
Jmhhh
Jmiii
Jmjjj
Jmkkk
Jmlll
Jmmmm
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FIG. 13. Typical Franciscan terrain, showing characteristic irregular "knobby" topography. Chiefly sandstone and shale, with some basalt. Panoche covered with sagebrush on the far left. North side of Los Muertos Creek.

FIG. 14. Grass-covered belt of Moreno shale, bordered on the right by brush-covered Call sandstone member of Panoche group. View west from Paynes Creek.

FIG. 15. Prominent outcrops of Call sandstone member of Panoche group, steeply dipping toward the observer. Call Mountains, looking north between Paynes Creek and Bitterwater Creek.

FIG. 16. Highly contorted Monterey shale adjacent to a transverse fault. Road cut, half a mile northwest of head of Bear Valley.

FIG. 17. Graded bedding in Call sandstone member of Panoche group. Shows gradation (from left to right) from sandstone through siltstone to clay-shale, followed by an abrupt change to sandstone. Top side of beds is to right. East bank of Paynes Creek.

FIG. 18. Intraformational contortion in siltstone, Call sandstone member of Panoche group. West bank of Moody Gulch, Panoche quadrangle.

FIG. 19. Pinnacles formation, dipping north, forming "The Balcony," north end of Pinnacles National Monument.

FIG. 20. Willow Creek Peak, formed of steeply dipping rhyolite flows, bordered by an area of vent tuff in the foreground. View west from Willow Creek.

FIG. 21. Columnar jointing in rhyolite. The columns, now gently dipping toward the east, are perpendicular to flow planes tilted 80° W. Southwest slope of Willow Creek Peak.

FIG. 22. Cross-bedded concretionary sandstone of Etchegoin group. Top side of beds to the left; beds are overturned toward the northeast. North bank of San Benito River at mouth of Sulphur Creek.

FIG. 23. Oyster beds, containing *Ostrea vespertina* and *Littorina mariana*, near the top of the Etchegoin group. Road cut a quarter of a mile southwest of San Benito.

FIG. 24. San Benito gravels, gently dipping northwest. Panoche group underlies the gravels on the left and in the foreground. View southwest from Call Mountains.

FIG. 25. Etchegoin cliffs east of the San Benito River. The beds are overturned about 60° toward the northeast. Looking northeast from near San Benito.

FIG. 26. Terraces north of Tres Pinos Creek. Two levels may clearly be distinguished; toward the right there are three levels. Tres Pinos sandstone forms rocky hills in middle distance; Panoche group forms rounded hills on the skyline.

FIG. 27. Two cycles of erosion developed in the Franciscan group in the Diablo Range. View west of Las Aguilas Creek, showing late mature valleys (right) emptying into youthful canyon (left).

FIG. 28. Cliffs and badlands developed in San Benito gravels north of Tres Pinos Creek just north of Bradford fault.

FIG. 29. View northwest along the San Andreas fault, showing sag pond Northwest of Jungle Inn.

FIG. 30. Large landslide opposite mouth of Willow Creek, looking east. *Photograph by R. W. Swanson.*

The Santa Margarita is fairly resistant to erosion, forming comparatively steep slopes. It is covered chiefly by low brush of the sagebrush type, especially on southerly slopes, and by oaks and grass on some of the northerly slopes.

The typical strata of the Santa Margarita are well-cemented grayish to whitish calcareous sandstones, containing "reef" beds of large and small oysters, Pectens, barnacles, and bryozoans. Some "reef" beds are composed almost entirely of comminuted fragments of small oyster shells. There are also beds of gray marl, weathering to a characteristic lumpy surface, which contain abundant molds of Crepidulas and pelecypods.

A small body of rather pure opaline chert was found near the top of the Santa Margarita, half a mile south of Pine Rock. Beds of light-gray limestone occur elsewhere, grading into arenaceous limestone and calcareous sandstone. Dark-colored clay-shale is rather common toward the bottom of the exposed section. Some of this contains diatoms. Interbedded brownish sandstones and clay-shales, similar to those of the Etchegoin, are common in the lower part of the section. The uppermost beds in places have been stained reddish by surface waters flowing from the overlying basal red beds of the Etchegoin group. The strata may thus be confused with the red beds from a distance, but close examination reveals the superficial character of the coloration.

Lenticular pebbly conglomerate layers occur at various places in the Santa Margarita formation. One layer about 4 feet thick was examined west of Pine Rock. It contains subrounded to subangular pebbles, averaging $\frac{1}{2}$ to 1 inch in diameter, ranging up to 5 inches. Large oysters occur in the conglomerate, also below and above it. Slightly more than half the pebbles are of Franciscan origin, and consist of green, red, gray, white, and varicolored chert; bluish-gray well-cemented feldspathic sandstone, silica-carbonate rock, serpentine, and greenstone. The remaining pebbles are chiefly pre-Franciscan, mainly porphyries, as well as some black quartzite, light-colored quartzite, and black chert. Other pebbles noted include vein quartz, a few uncertainly identified as flow-banded rhyolite, one of biotite granite, and two light-colored sandstones (probably Tertiary).

The Santa Margarita formation contains abundant fossils, belonging to a relatively few species. The most characteristic forms are *Ostrea titan* var. *eucorrugata, Pecten crassicardo,* and *Pecten estrellanus.* The last two species range down into the Temblor, but B. L. Clark, who examined the specimens, states that these appear to be of the Santa Margarita type (upper Miocene). One incomplete specimen of an *Astrodapsis* was found, which resembles *A. margaritanus,* believed to be characteristic of the Santa Margarita. Bryozoans and large Tamisomas are abundant.

The following species were determined by B. L. Clark and the writer:

ECHINOIDEA

Astrodapsis cf. margaritanus Kew

BRYOZOA

Undetermined

PELECYPODA

Apolymetis biangulata (Carpenter)
Clementia (Egesta) martini (Clark)
Cryptomya sp.
Ostrea titan Conrad var. eucorrugata Hertlein
Ostrea sp. (small)
Pecten (Lyropecten) crassicardo (Conrad)
Pecten (Lyropecten) estrellanus (Conrad)
Protothaca staminea (Conrad)
Pseudocardium densatum (Conrad)
Thracia sp.

GASTROPODA

Crepidula praerupta Conrad
Natica ? sp.
Surculites (Megasurcula) cf. carpenterianus (Gabb)

CIRRIPEDIA

Balanus concavus Bronn
Tamiosoma gregaria Conrad

PISCES

Undetermined fish remains

MISCELLANEOUS

Diatoms, including Coscinodiscus ?

A sample of clay-shale from near the bottom of the Santa Margarita was examined microscopically by H. G. Schenck. He reports abundant fish remains; also diatoms, many of which are large, discoidal types, probably including *Coscinodiscus*. He states: "The diatoms are not fragmented, but instead are preserved as unbroken 'pill boxes.' This type of preservation is common in diatomites of Delmontian age."[8]

Etchegoin Group (Pliocene)

The Etchegoin group (Anderson 05, pp. 178-192) is a series of sandstones, shales, and conglomerates of Pliocene age, whose maximum thickness is 3500 feet. The term is herein used as Nomland (17) used it, to include the Jacalitos, Etchegoin, and possibly also the San Joaquin formations of the Coalinga district, which cannot be distinguished lithologically in the field in this region.[9] Only one cartographic division was separated—a series of red beds of non-marine origin at the base, which is of quite different character from the rest of the group.

The Etchegoin group lies chiefly in a narrow belt, 2 miles wide, between the San Andreas and San Benito fault zones. Here it reaches its maximum thickness of 3500 feet. In the Sulphur Creek area the Etchegoin extends 2 miles farther east, overlapping the sediments of the Butts Ranch syncline, but with a reduced thickness of only 750 feet. The main belt, along the San Benito River, continues northwest of the quadrangle beneath the San Benito gravels and reappears in the Lomerias Muertos, northwest of Hollister (Kerr and Schenck 25, fig 3). To the southeast the belt extends through Priest Valley and Waltham Canyon (where it has a thickness of 8000 feet) into the Coalinga district.

The basal red beds of the main Etchegoin belt rest disconformably upon the Santa Margarita formation southwest of the San Benito River

[8] Letter dated February 15, 1941.

[9] Although there is a disadvantage in using the same name for a group and a formation within the group, the alternative of supplying a new name for the group would seem even more objectionable in this case. The well-known term Etchegoin has been perhaps as widely used as a "group" term (Nomland 17; Reed 33, pp. 235-233) as in the more restricted sense. It is conveniently used as such in many parts of the Coast Ranges where the Pliocene section cannot be subdivided into units corresponding exactly with those of the Coalinga district (Woodring, et al. 40, p. 27) even though faunal evidence of these various divisions may be present.

One bit of evidence for the disconformity is the discovery in the red beds of a rounded, reddish-stained fragment of *Ostrea titan* derived from the Santa Margarita. In places there appears to be a difference in dip between the two formations, but this is uncertain because the attitudes of both are so variable. The eastern belt of Etchegoin rests with as much as 90° angular discordance upon the Upper Cretaceous, middle Eocene, and middle Miocene sediments of the Butts Ranch syncline.

The interbedded sandstones and shales of the Etchegoin vary in their resistance to erosion. Where the sandstones dip steeply, they generally produce narrow ridges separated by troughs or low, slumped belts of shale. The basal red beds are less resistant than the overlying sandstones and shales and form more gentle slopes. The formation is generally covered by low brush of the sagebrush type, or in places by dense chaparral (chamise and manzanita). Some of the northerly slopes support oaks and grass. The basal red beds are covered only by grass, or by grass and scattered oaks.

The Etchegoin group consists mainly of poorly sorted cross-bedded brownish sandstones, pebbly conglomerates, and dark-colored clay-shales. Massive concretionary sandstones with reddish-brown "cannon-ball" concretions 2 to 3 feet in diameter are common. Well-cemented calcareous sandstone "reef" beds containing chiefly *Dendraster gibbsii* and *Anadara trilineata* frequently occur. The sandstones contain sub-angular grains of quartz, feldspars, biotite, amphiboles and pyroxenes, rock fragments, and a variety of heavy accessory minerals, including such uncommon types as staurolite and kyanite. Clinozoisite, enstatite, epidote, garnet, glaucophane, green hornblende, magnetite, rutile, sphene, and zircon are also present. The source is evidently mixed. Some of the "blue sandstones" which are common in the Coalinga district appear in the Etchegoin south of San Benito. The color results from a thin glaucous coating on many of the sand grains, which has often been attributed to opal.

The shales of the Etchegoin vary from well-bedded chocolate-brown clay-shales to lighter-brown silty micaceous shales. These commonly occur as definite units 10 to 50 feet thick. They are often gypsiferous. Sandy shales and shaly sands are also interbedded with the sandstones in layers a few inches thick.

Loosely compacted oyster beds, composed largely of shells of *Ostrea vespertina* in a buff sandy matrix, appear near the top of the formation. Impure marly limestone occurs near the base, just west of Pine Ridge.

Conglomerates in the Etchegoin generally contain only small pebbles, ½ to 2 inches in diameter, although some range up to 6 inches. Most of the pebbles are subangular to subrounded. The pebbles are chiefly of Franciscan source, including Franciscan sandstone, chert, glaucophane schist, and altered basic igneous rocks. Pebbles of Cretaceous sandstone are common. The usual well-rounded pre-Franciscan porphyries, black cherts, and quartzites are also represented. Granite pebbles are rare.

Stratigraphic Section

The best-exposed section across the Etchegoin group is along Sulphur Creek and the San Benito River west of the mouth of the creek.

The beds stand nearly vertically throughout, facilitating measurement of thickness. Here are nearly continuous exposures of about 3400 feet of beds. Both the base and top of the formation are faulted out. Probably not more than 100 feet of beds are missing at the base; the missing thickness at the top is unknown but is probably not more than a few hundred feet. This section was measured as follows (thicknesses measured with tape to nearest foot):

Section of Etchegoin Group Along Sulphur Creek and San Benito River

		Thickness (feet)
	Top not exposed (within 50 feet of fault contact with Franciscan)	
1.	Sandy shale and sandstone	35
2.	Massive gray medium-grained sandstone; with a few finer-grained brownish sandstone partings, 1 to 2 feet wide, containing abundant fossils, chiefly *Anadara trilineata*	50
	No exposure	29
3.	Fine-grained brownish silty micaceous shale. *Anadara trilineata, Schizothaerus nuttallii* var. *pajaroanus, Polinices*	16
4.	Massive light-brown cross-bedded sandstone, with brownish concretionary layers	36
5.	Chocolate-brown clay-shale, highly fractured, stained reddish brown on fractured surfaces. Much gypsum. *Anadara trilineata, Mytilus coalingensis, Protothaca tenerrima, Schizopyga moraniana, Thais canaliculata, Olivella biplicata*	55
6.	Massive gray to light-brown concretionary sandstone	105
	No exposure	160
7.	Bluish-gray silty micaceous shale	8
8.	Massive gray sandstone	6
	No exposure	10
9.	Fine-grained brownish sandstone	12
10.	Gray coarse sandstone and pebbly conglomerate; pebbles average ¼"-1" in diameter	2
	No exposure	23
11.	Gray medium-grained sandstone	55
12.	Pebbly conglomerate, highly fossiliferous	1
13.	Massive gray medium-grained sandstone, with a few well-cemented concretionary layers averaging 1' in thickness	47
14.	Pebbly fossil "reef" layer. *Clinocardium meekianum, Macoma vanvlecki, Solen perrini, Spisula coalingensis, Thais etchegoinensis*	2
15.	Fine-grained brownish to gray sandstone and sandy shale	32
16.	Pebbly fossil "reef" layer	1
17.	Massive gray sandstone with fossil "reef" layers. *Trachycardium quadragenarium*	50
18.	Fossil "reef" layer. *Clinocardium meekianum, Pseudocardium densatum, Solen perrini*	2
19.	Massive cross-bedded concretionary gray sandstone, with pebbly well-cemented layers. *Clinocardium, Dendraster*	104
	(Mouth of Sulphur Creek)	
20.	Pebbly well-cemented fossiliferous conglomerate. Pebbles average ½"–1" in diameter. *Anadara trilineata, Thais lamellosa*	6
21.	Medium- to coarse-grained gray sandstone with well-cemented pebbly layers. Pebbles average ¼" in diameter	58
22.	Fine- to medium-grained brownish sandstone, highly fossiliferous. *Anadara trilineata, Moniliopsis mercedensis*	11
23.	Brownish sandy shale and fine-grained sandstone	32
24.	No exposure	50
25.	Chocolate-brown clay-shale, and silty shale. Occasional fossil layers. Much gypsum. *Compsomyax subdiaphana*	74
26.	Brown concretionary sandstone	5
27.	Chocolate-brown gypsiferous clay-shale and silty shale; sandy shale and fine-grained sandstone toward top. *Anadara trilineata, Crepidula onyx, Crepidula princeps*	60
28.	Brownish sandy shale and sandstone	42
29.	Massive brown sandstone, with concretionary layers	32
30.	Brownish sandy shale and sandstone	55
31.	Massive concretionary sandstone. Pebbly conglomerate at base; pebbles up to 3" or 4" in diameter	38
32.	Well-bedded brownish sandstone with thin shaly partings. Light pebbly conglomerate at base	61
33.	Massive brownish concretionary sandstone. *Anadara trilineata*	103
34.	Well-bedded sandstone with thin shaly partings, and occasional pebbly layers	39
35.	Massive brownish sandstone with pebbly layers and concretionary layers	116
36.	Well-bedded sandstone with shaly partings	10
37.	Massive brownish sandstone with pebbly layers and concretionary layers	34

	Thickness (feet)
38. Chocolate-brown gypsiferous clay-shale and silty shale; sandy shale and fine-grained sandstone toward top. *Anadara trilineata, Macoma nasuta, Macoma secta, Mytilus coalingensis, Schizothaerus nuttallii* var. *pajaroanus, Cancellaria rapa, Crepidula princeps, Polinices lewisii*	80
39. Heavy well-cemented conglomerate layer. Pebbles average 2" to 3", up to 6" in diameter	5
40. Massive brown concretionary sandstone	26
41. Sandy shale and sandstone	5
42. Massive brown concretionary sandstone	62
43. Clay-shale and silty shale	7
44. Massive brown sandstone	13
45. Clay-shale and silty shale, more sandy toward the top	38
46. Thin-bedded brown sandstone, with few concretionary layers	41
47. Chocolate-brown clay-shale and brownish silty shale	16
48. Brown concretionary sandstone, with some thin-bedded layers, and occasional fossiliferous layers	137
49. Silty micaceous shale and sandy shale	16
50. Brown concretionary sandstone, with some thin-bedded layers, and occasional fossiliferous layers	85
51. Silty micaceous shale, and chocolate-brown clay-shale, highly fractured, more sandy toward the top	67
(At gate in Sulphur Creek)	
52. Massive brown concretionary sandstone, with prominent fossil "reef" beds. *Dendraster gibbsii, Glycymeris grewingki, Pseudocardium densatum, Pododesmus macroschismus, Calliostoma* cf. *coalingense, Calyptraea filosa, Schizopyga moraniana, Thais canaliculata, Tamiosoma gregaria*	25
53. Fine-grained highly jointed brownish sandstone	32
54. Chocolate-brown clay-shale, highly fractured, stained reddish brown on fractured surface, and silty micaceous shale. *Macoma nasuta, Macoma secta*	73
55. Massive brown concretionary sandstone, with light pebbly layer at base	16
56. Brownish silty shale and clay-shale	23
57. Brownish well-bedded sandstone	45
58. Chocolate-brown clay-shale, highly fractured, stained reddish brown on fractured surface, and silty micaceous shale	64
59. Brownish sandstone "reef" bed. *Anadara trilineata, Protothaca tenerrima, Thais etchegoinensis, Balanus concavus*	2
60. Interbedded brown sandy shale and resistant gray sandstone "reef" beds, with pebbly layers. Sulphur springs. *Mytilus coalingensis, Protothaca tenerrima*	95
61. Massive gray sandstone and "reef" beds. Many sulphur springs. *Dendraster gibbsii, Mytilus coalingensis, Taras parilis, Protothaca tenerrima*	81
62. Brown silty micaceous shale and sandy shale, interbedded with brown sandstone. Some chocolate-brown clay-shale. Highly fractured and brecciated	178
63. Brown concretionary sandstone	16
No exposure	32
64. Brown concretionary sandstone	16
65. Basal red beds. Reddish to bluish poorly sorted gravels, sands and clays. Abundant Franciscan debris. No marine fossils. Horse tooth found just to south of line of section	397
Fault contact with Franciscan.	
Total	3360

Basal Red Beds

The only lithologic division of the Etchegoin group which may be readily distinguished and mapped over the entire area is the basal series of red beds. This is a key horizon which proved of great importance in working out the structure of the region. It clearly marks the contact between the Etchegoin and Santa Margarita, which otherwise would be difficult to locate.

The red beds average 500 feet in thickness, ranging in general from 400 to 600 feet. They occur everywhere that the base of the Etchegoin is exposed, except for the eastern belt overlapping upon the Butts Ranch syncline. They consist mainly of poorly sorted gravels, sands, and clays which nearly everywhere are strongly colored a deep red, with occasional streaks of blue or green. Occasionally the gravels and sands are well cemented into conglomerate and sandstone.

The pebbles average 2 to 3 inches, ranging up to 6 or 8 inches in diameter and are mainly subangular to subrounded. They represent a larger proportion of Franciscan debris than most conglomerates in this

region. This includes Franciscan sandstone, serpentine, chert, glaucophane schist, and various altered basic igneous rocks. In addition there are numerous pebbles of brownish to greenish feldspathic, biotitic sandstones which are doubtless Cretaceous, and a few other sandstones which may be Tertiary. The usual well-rounded pre-Franciscan porphyries, black cherts, and quartzites are rarer than in most of the other formations.

The basal red beds are most likely of nonmarine origin. This, of course, is true of red beds in general, although there may be some exceptions. In this case, the lithologic criteria are supported by a certain amount of faunal evidence—the lack of any marine organisms, although these are quite abundant in the overlying Etchegoin; and the presence of vertebrate remains. The latter are very scarce: a horse tooth found by Carl Bleifuss of Hollister just south of Sulphur Creek, and camel remains discovered farther southeast, in the Priest Valley quadrangle. The latter were tentatively placed as Pliocene by R. A. Stirton (Mielenz 39, p. 205).

Overlap of Etchegoin Group Onto Butts Ranch Syncline

The belt of Etchegoin extending east of the San Benito fault zone onto the Butts Ranch syncline in the headwaters of Sulphur Creek differs in several important characteristics from the main belt along the San Benito River: (1) the thickness is greatly reduced, being not more than 700 feet, as compared with 3400 feet in the main belt; (2) the deposits are much coarser, consisting mainly of gravels and heavy conglomerates, interbedded with sandstone; pebbles and boulders are commonly 6 to 8 inches in diameter; there is practically no shale; (3) faunal evidence indicates that only the Etchegoin proper (middle Pliocene) is present.

These characters point to a shoreline encroaching to the east over the previously folded Butts Ranch syncline during Etchegoin (middle Pliocene) time. The coarseness of deposits, abundance of boulders, and relative absence of shale indicate close proximity to a shoreline lying to the east. This is borne out by the great reduction in thickness in this direction. It is doubtful if the sea extended much farther east than the present position of these deposits, 1 mile west of Butts Ranch. Following the Butts Ranch syncline eastward to Pimental Canyon in the Panoche quadrangle, only nonmarine Pliocene red beds are found.[10]

A similar eastward transgression of the Etchegoin, compared with the Jacalitos, occurs southeast of this area in the White Creek syncline, according to Nomland (17, p. 198). He states:

> "In the White Creek Syncline the lower part of the upper Etchegoin rests uncomformably on the upper Cretaceous. The basin of deposition of the upper Etchegoin evidently had a greater extent in this direction than in the lower Etchegoin, as shown by this overlap."

Fossils, Correlation, and Age

The Etchegoin group contains the most abundant and best preserved fossils found in this region. A total of 68 species was identified. The fauna consists dominantly of pelecypods, and subordinate gastropods. The echinoid *Dendraster gibbsii* is common in sandstone "reefs."

The Jacalitos (lower Pliocene) and Etchegoin (middle Pliocene) divisions of the Coalinga district are both present, and the San Joaquin

[10] Mielenz, R. C., personal communication, 1939.

(upper Pliocene) may also be represented. The Jacalitos is established by the presence of the forms *Astrodapsis spatiosus* and *Pecten estrallanus* var. *terminus,* which are unknown outside of this zone. Other species confined to the Jacalitos in this area, but not so limited in other regions, are *Dendraster ashleyi,* and *Thais* cf. *shumanensis.* Longer-range species occurring with the above forms are *Dendraster gibbsii, Balanus concavus,* and *Tamiosoma gregaria.* The Jacalitos beds were recognized in only two areas: in a narrow belt immediately overlying the basal red beds, southwest of the San Benito River; and in a fault sliver along the Pine Rock fault on the San Benito River bank opposite Buckeye Canyon. The exact boundary between the Jacalitos and Etchegoin could not be established, but the Jacalitos includes at least 400 feet of strata above the basal red beds southwest of the San Benito River.

By far the greatest portion of the Etchegoin group in this region is thought to belong to the restricted Etchegoin, of middle Pliocene age. This includes most of the 3400 feet of strata exposed in the Sulphur Creek section, except for a few hundred feet at the base. Forms believed diagnostic of this formation are *Moniliopsis mercedensis* and *Schizopyga moranianus.* Not so distinctive, but common throughout, are *Dendraster gibbsii, Anadara trilineata, Clinocardium meekianum, Pseudocardium densatum, Schizothaerus nuttallii* var. *pajaroanus, Prototothaca tenerrima,* and *Polinices reclusianus.*

The San Joaquin formation (upper Pliocene) of the Coalinga district is believed to be represented by a thin belt of oyster beds at the top of the Etchegoin group. These beds are exposed half a mile west of San Benito, and in a fault sliver along the San Andreas fault zone near the Jungle Inn. The faunal assemblage includes *Littorina mariana, Mya japonica, Macoma irus,* and *Ostrea vespertina.* Arnold (09, p. 43) lists this assemblage from his "upper *Mya* zone" (except that he lists *Ostrea vespertina* as the variety *sequens*) now included in the San Joaquin formation. Nomland (17, p 214) states that *Littorina mariana* is unknown in other horizons, but Woodring et al. (40, p. 60) record this species in the upper part of the Etchegoin as well as in the San Joaquin formation. However, Woodring et al. record *Ostrea vespertina* and its variety *sequens* only from the San Joaquin formation. It seems possible, therefore, that the beds containing this assemblage are equivalent to the San Joaquin formation. If this proves to be true, then at least 300 feet of beds west of San Benito belong to the San Joaquin formation, the base of which could not be established.

The fossils in the following list were determined by B. L. Clark and the writer.

ECHINOIDEA

Astrodapsis spatiosus Kew
Dendraster ashleyi Arnold
Dendraster gibbsii (Rémond)

PELECYPODA

Anadara trilineata (Conrad)
Chione elsmerensis English
Clinocardium meekianum (Gabb)
Compsomyax subdiaphana (Carpenter)
Cryptomya californica (Conrad)
Cryptomya quadrata Arnold
Dosinia jacalitosana Arnold

PELECYPODA—Continued

Glycymeris grewingki Dall
Lucina (Lucinoma) acutilineata Conrad
Lucina (Miltha) xantusi (Dall)
Macoma irus (Hanley)
Macoma nasuta (Conrad)
Macoma secta (Conrad)
Macoma vanvlecki ? Arnold
Macoma sp.
Mactra sp.
Mya japonica Jay
Mytilus coalingensis Arnold
Mytilus kewi Nomland
Ostrea vespertina Conrad
Pachydesma stultorum (Mawe)
Pachydesma trigonalis (Nomland)
Pandora punctata Conrad
Panope generosa Gould
Pecten (Lyropecten) estrellanus (Conrad) var. terminus Arnold
Pecten (Patinopecten) healyi Arnold var.
Pododesmus macroschismus (Deshayes)
Protothaca staminea (Conrad)
Protothaca tenerrima (Carpenter)
Pseudocardium densatum (Conrad)
Saxidomus nuttalli Conrad
Schizothaerus nuttallii (Conrad)
Schizothaerus nuttallii (Conrad) var. pajaroanus (Conrad)
Semele ? sp.
Siliqua lucida (Conrad)
Solen perrini Clark
Spisula albaria (Conrad)
Spisula catilliformis (Conrad)
Spisula coalingensis (Arnold)
Spisula hemphilli (Dall)
Taras parilis (Conrad)
Trachycardium (Dallocardia) quadragenarium (Conrad)
Volsella recta (Conrad)
Zirfaea pilsbryi Lowe

GASTROPODA

Calliostoma cf. coalingense Arnold
Calyptraea filosa (Gabb)
Cancellaria rapa Nomland
Crepidula onyx ? Sowerby
Crepidula princeps Conrad
Kelletia (Kelletia) kettlemanensis (Arnold)
Littorina mariana Arnold
Moniliopsis mercedensis (Martin)
Olivella biplicata (Sowerby)
Olivella pedroana (Conrad)
Polinices (Euspira) lewisii (Gould)
Polinices (Neverita) reclusianus (Deshayes)
Schizopyga californiana (Conrad) var. coalingensis (Arnold)
Schizopyga moraniana (Martin)
Thais (Nucella) canaliculata (Duclos)
Thais (Nucella) etchegoinensis Arnold
Thais (Nucella) lamellosa (Gmelin)
Thais (Nucella) cf. shumanensis Carson

SCAPHOPODA

Dentalium sp.

CIRRIPEDIA

Balanus concavus Bronn
Tamiosoma gregaria Conrad

San Benito Gravels (Plio-Pleistocene)

The San Benito gravels (Lawson 93b, p. 153; Kerr and Schenck 25, pp. 468-469, 477, 490) are a thick series of non-marine deposits of Plio-Pleistocene age which blanket much of the northwestern part of the San Benito quadrangle. The formation is younger than the strongest folding which affected the region, and overlaps nearly all of the older formations. It rests with angular discordance of as much as 90° upon the Franciscan and Cretaceous, and as much as 35° upon the Etchegoin group. It has been subjected to gentle folding and faulting of comparatively small displacement.

The main belt of San Benito gravels lies on either side of Tres Pinos Creek, extending as far east as Salt Creek, covering an area about 3 miles wide and 12 miles long. This belt continues northwest into the Gonzales and Hollister quadrangles. The maximum thickness in this belt is over 1500 feet, and may reach 2000 feet. A thickness of 1250 feet is revealed in a single exposure at the head of Sulphur Creek. Other belts of San Benito gravels occur just southwest of the Pine Rock fault, southwest of the San Andreas fault, and in scattered areas covering the Franciscan group. The thickness exposed in these areas is not more than a few hundred feet.

The San Benito gravels are less resistant to erosion than most of the older formations and tend to form broad, gentle dip slopes, and steep scarp-slopes often intricately carved into "badlands." The formation is covered with grass, or with grass and scattered oaks. In some places a sparse growth of short brush of the sagebrush type occurs on the steeper slopes.

Some of the gravels have a gray or whitish appearance which contrasts sharply with the brownish appearance of the Etchegoin; elsewhere they are colored in shades of red, and show smaller areas of blue or green, as in the belt northwest of Los Muertos Creek. The coloration is generally not so pronounced as in the basal red beds of the Etchegoin.

The San Benito gravels consist of gravels, sands, and clays, in part consolidated into conglomerate, sandstone, and clay-shale. The sorting is generally poor, and rapid variations in grain size occur both laterally and vertically. Coarse cross-bedding, channeling, and rapid lensing of gravel layers are prominent features.

The sands and sandstone contain angular to subangular grains of variable size, intermingled with silt and clay. The grains include quartz, feldspar, biotite, many rock fragments, and a variety of heavy minerals, including actinolite, augite, diopside, enstatite, green, brown, and blue-green hornblende, tremolite, clinozoisite, epidote, magnetite, and sphene. Some of the material is incoherent whereas certain beds are well cemented. Bands of stronger cementation sometimes extend through the formation at right angles to the bedding.

Clays, clay-shales, and siltstones occur in distinct beds or intermingled with the beds of sand and gravel. The clays are usually yellowish to brownish in color. They are rather soft, incoherent, and poorly bedded. Occasional beds of impure lignite are interbedded with the clays.

Pebbles in the gravel and conglomerate layers range from a few inches to a foot or two in diameter, and are usually subangular to subrounded, depending upon their size. The pebbles are of a great many different types. Franciscan pebbles are in general most abundant, including typical Franciscan sandstone, chert, serpentine, glaucophane and actinolite schist, and greenstone. Greenish feldspathic, biotitic sandstone pebbles resembling Cretaceous sandstone are often present. Sandstone pebbles and boulders containing Etchegoin fossils sometimes occur, especially in the immediate vicinity of that formation. In some places whitish-weathering siliceous shale pebbles occur, which could have been derived from the Moreno, Kreyenhagen, Temblor, or Monterey shales. Granite pebbles are common in some places, rare in others.

The "pre-Franciscan" porphyries, black cherts, and quartzites are less common than in many of the older formations. They are nearly always well rounded, and were evidently derived from previous conglomerates. As would be expected, the relative abundance of the various types of pebbles varies from place to place and is influenced by the immediately underlying or adjacent rock.

In some places, particularly north of Tres Pinos Creek, there occur a great many pebbles of a rather fresh porphyritic volcanic rock. The color is purplish to reddish-brown, and a lens reveals distinct plagioclase phenocrysts $\frac{1}{2}$ to 3 mm in diameter. Microscopically the phenocrysts are seen to be labradorite ($Ab_{45}An_{55}$). They are accompanied by augite, partially or completely filled with magnetite, and needle-like crystals of apatite. The groundmass is hyalopilitic, containing very small lath-shaped crystals or microlites in a brownish glass. This particular pebble would be called basalt, but others might be called andesite. No similar rocks were observed in place or as pebbles in any of the older formations, and their source is unknown; they may have come from a volcanic area lying to the north in the Quien Sabe quadrangle.

The San Benito gravels have yielded a few vertebrate fossils and fresh-water mollusks. Kerr and Schenck (25, p. 476) reported camel remains and horse teeth identified as *Equus* near *occidentalis* Leidy, which they considered of Pleistocene age. However, R. A. Stirton has examined these horse teeth and another submitted by the writer and states that they cannot be placed closer than upper Pliocene or lower Pleistocene.

Fresh-water clams, identified as *Anodonta wahlamatensis,* and undetermined gastropods were found in a fine-grained well-cemented yellowish sandstone. Kerr and Schenck (25, p. 476) reported *Anodonta* sp. and *Pyrgulopsis vatesiana* in the Paicines formation, which they considered of Pliocene age. They state that no contact was found between the Paicines beds and the San Benito gravels and that "it is practically impossible to separate" the two; their basis for establishing the two formations was the discovery of Pliocene invertebrates in one area and Pleistocene vertebrates in another. However, the discovery of similar invertebrates by the writer in an area mapped by Kerr and Schenck (25, fig. 3) as San Benito gravels, together with the fact that the vertebrates may be Pliocene or Pleistocene, would seem to eliminate any basis for separating the two formations. No contact of any sort has been found between the beds containing the invertebrate and vertebrate fossils; the lithologies are identical; and since the fossils now apparently signify no difference in age, it seems logical to include these beds in one formation. Hence the term "Paicines formation" is not used in this paper; the older term San Benito gravels includes both the Paicines formation and San Benito gravels of Kerr and Schenck.

The best indications from the invertebrate and vertebrate fossils are that the San Benito gravels are upper Pliocene, or Pleistocene, or both.

The San Benito gravels are definitely non-marine deposits, as evidenced by: (1) poor sorting; (2) rapid variation in grain size and character of material, both laterally and vertically; (3) coarse cross-bedding, channeling, abrupt lensing of gravel beds; (4) distinct red

and blue coloration in places; (5) presence of non-marine fossils; absence of marine fossils.

The gravels are most likely flood-plain deposits derived by erosion from the ancestral mountains which were formed in this region by the strong upper Pliocene deformation.

Landslides (Quaternary)

Landslides are quite common in the San Benito quadrangle, particularly on the steep front of the Diablo Range just northeast of the San Benito River. Only the more prominent of these were mapped. The slides have developed from various formations, but chiefly from Franciscan serpentine, the relatively unconsolidated San Benito gravels, and soft Cretaceous shales.

The largest landslide lies northeast of the mouth of Willow Creek. It has a length of 1½ miles and an average width of half a mile. The surface has an average slope of 9°. It heads in Franciscan serpentine and the basal red beds of the Etchegoin, but it also includes large blocks and smaller debris of the Etchegoin and San Benito gravels. A much smaller, more recent mass of serpentine has flowed over this landslide near its head.

An interesting recent mudflow is developed from the San Benito gravels in sec. 30, T. 15 S., R. 8 E., M. D., and sec. 25, T. 15 S., R. 7 E., M. D. A considerable movement on this slide followed some severe storms in the spring of 1938. The flow dammed up the stream at its foot, forming a lake behind it. In the summer of 1938 this lake rose nearly to the top of a windmill which had once been placed in the stream bed.

Terrace Deposits (Quaternary)

Terrace deposits border the two largest streams of the area, the San Benito River and Tres Pinos Creek. They consist of unconsolidated gravel, sand, silt, and clay. Two or three levels occur in many places; these separate levels were mapped wherever possible.

The best developed terraces occur north of Tres Pinos Creek and Los Muertos Creek in the northwestern part of the quadrangle. Here occur as many as six different levels, two of which are very prominent. North of the junction of the two creeks four sets of terraces were noted as follows:

	Height above stream (feet)	*Approximate elevation (feet)*	*Maximum width (feet)*
1	20	770	800
2	50	800	2000
3	150	900	700
4	300	1050	2000

Just west of the McKanna Ranch on the north side of Los Muertos Creek are six terrace levels, as follows:

	Height above stream (feet)	*Approximate elevation (feet)*	*Maximum width (feet)*
1	10	800	900
2	75	865	400
3	100	890	1000
4	120	910	200
5	175	965	500
6	375	1165	800

Alluvium (Quaternary)

Recent alluvium, unconsolidated gravel, sand, silt, and clay, occurs in the beds of many of the larger streams of the region. The largest areas of alluvium are in the first-cycle valleys at the head of Las Aguilas Creek.

STRUCTURE

The San Benito quadrangle is divided into two structural provinces which have different basement rocks and have reacted differently to deformational forces. The Gabilan Range is "thin blanketed"; it has a granite basement, and a sedimentary cover ranging from 0 to 3000 feet in thickness. It has been deformed chiefly by block faulting, and some gentle folding of the thicker sedimentary sections. The Diablo Range is "thick blanketed"; it has a basement of at least 10,000 feet of easily foldable Franciscan strata, overlain by as much as 13,000 feet of later sediments. It has been deformed by folding and thrust faulting, and strong overturning in places. At least three epochs of folding are represented. The boundary between the two basements is formed by the Bear Valley fault, lying close to and roughly paralleling the San Andreas fault zone.

Diablo Range

The Diablo Range comprises the following structural belts, from southwest to northeast:

1) The San Benito River area, a belt of highly folded, overturned, and faulted Franciscan, upper Miocene, and Pliocene strata between the Bear Valley fault and the San Benito fault zone. It includes the San Andreas, Pine Rock, and Paicines faults. The deformation was chiefly upper Pliocene, with some reversals of fault movements indicated in the Pleistocene or Recent.

2) The Butts Ranch syncline in the southeastern part of the area, strongly folded between the middle Miocene and middle Pliocene (most likely between middle and upper Miocene).

3) A belt of San Benito gravels overlapping the Butts Ranch syncline to the northwest. This was gently warped into a broad, plunging syncline and faulted in the Pleistocene or Recent.

4) A broad expanse of folded Franciscan, the chief fold within the quadrangle being the Tres Pinos syncline. The main folding may have occurred at the same time as that of the Butts Ranch syncline. The belt is bounded on the southwest by the Browns Valley and Bradford faults, which have thrust Franciscan over the Cretaceous, probably during the upper Pliocene. The Bradford fault shows reversal of movement in the Pleistocene or Recent.

The various structural features will be discussed in turn, considering first the faults, then the folded structures.

San Andreas Fault Zone

The San Andreas fault, longest-traced fault and most important known active fault in California, extends in a northwest direction through the San Benito quadrangle. It is known to extend north as far as Point Arena and south to Imperial Valley.

The fault plane is essentially vertical, as indicated by the straight course across irregular topography. Recent movement along the fault has been chiefly horizontal, the southwest side having moved relatively northwest. This was demonstrated during the San Francisco earth-

quake of 1906, when a maximum horizontal displacement of 21 feet was measured. It is also indicated by stream offsets.

The San Andreas fault in part of this area consists of two or more subparallel faults with occasional en echelon branches, all of which show topographic evidence of recent movement, such as sag ponds, narrow troughs, scarps, and other rift features. The sum total of these breaks showing evidence of active horizontal movement is herein referred to as the San Andreas fault zone. As thus defined the fault zone has a width of 50 to 1500 feet, averaging 500 feet. This definition excludes nearby thrust faults which have sometimes been included in the San Andreas fault zone, but which possess an entirely different character and history.

Horizontal displacement of about half a mile is shown by offsets of streams and ridges along the San Andreas fault. This is best shown northeast of Little Rabbit Valley, just south of the San Benito quadrangle, in the Metz quadrangle. Here two southwestward-flowing streams have been deflected 1600 and 2700 feet to the northwest on the southwest side of the fault.

Displacements of several tens of miles along the San Andreas fault have been suggested in the past, but evidence against such large displacements has been presented by Reed (38) and by Taliaferro (38). In this area no evidence was found for displacements of any greater magnitude than those indicated by the stream offsets.

Bear Valley Fault

The Bear Valley fault marks the boundary between granite basement and Franciscan basement—the geological boundary between the Gabilan and Diablo Ranges. Its course parallels and in part coincides with that of the San Andreas fault, which may explain the attribution of some of its characteristics to the San Andreas fault in the past.[11] However, it deviates southwest from the San Andreas fault as much as half a mile in the San Benito quadrangle. The same or a similar fault has been described by Taliaferro (38) which also diverges southwest from the San Andreas fault, but in part follows its course, in the Priest Valley quadrangle.

The Bear Valley fault differs in several important characteristics from the San Andreas fault: (1) the fault-plane dips northeast, whereas the San Andreas fault-plane is vertical; (2) the Bear Valley fault shows no topographic evidence of recent movement; (3) it shows no evidence of horizontal displacement; (4) the Bear Valley fault shows evidence of movement dating back to the pre-Miocene, whereas no movement earlier than Pleistocene can be demonstrated along the San Andreas.

The Bear Valley fault shows an interesting succession of reversals of movement. These are indicated by the different sequence of formations on the two sides of the fault. The southwest side has a granite basement, overlain by Miocene sediments; the northeast side possesses a Franciscan basement, overlain by the San Benito gravels immediately

[11] Reed (33, p. 12): ". . . (The San Andreas fault) forms the boundary between a province on the east in which the oldest rocks exposed are . . . the Franciscan formation . . . , and a province to the west in which the Franciscan is not found."

adjacent to the fault. From these relations, the following movements are postulated (see fig. 6):

(1) The southwest side of the fault was upthrown and Franciscan was eroded off the granite on this side. Assuming that the fault-plane had its present dip, the movement was of normal type. Probably the entire Gabilan Range was uplifted by the displacement. The movement can be dated in this area only as pre-Monterey (upper Miocene), but elsewhere Taliaferro (41, p. 154) has dated it as post-Cretaceous and pre-Temblor, most likely Eocene.

(2) Franciscan on the northeast side of the fault was thrust over the granite and Monterey on the southwest side. Monterey sediments were eroded from the northeast side of the fault. The displacement was not nearly so great as in the first movement, because granite was still left far below the surface on the northeast side of the fault. The relative movement at this stage is indicated not only by the sequence of formations, but by a synclinal drag in the Miocene sediments on the southwest side of the fault. This movement occurred some time between the upper Miocene and Pleistocene, because the Plio-Pleistocene San Benito gravels are the youngest formation not involved in the action. It probably took place in the upper Pliocene, the demonstrated time of most active thrusting in this region.

(3) The most recent reversal of movement along the Bear Valley fault is a downthrow of the San Benito gravels on the northeast side. The displacement is slight compared to the earlier movements, averaging about 300 feet. Since the San Benito gravels are Plio-Pleistocene, the time of this movement must be late Pleistocene or Recent. It is analogous to a reversal of movement involving the San Benito gravels along the Bradford fault.

The absence of certain formations on one side or the other of the Bear Valley fault might be explained as indicating nondeposition rather than removal by erosion following successive fault movements. But this alternative hypothesis is contradicted by the nature of the sediments adjacent to the fault. If the fault marked a boundary of deposition, a coarsening of texture would be expected immediately adjacent to it. This does not occur in any of the three post-granitic formations involved:

(1) The Franciscan immediately adjacent to the Bear Valley fault shows no change in texture from its normal appearance everywhere in the Diablo Range. Cherts and shales occur against the fault; no conglomerates were observed in its vicinity.

(2) The Monterey shows a coarsening of texture toward the southwest, away from the Bear Valley fault; in fact an interfingering of marine and nonmarine sediments was observed in that direction. No evidence could be found of a shoreline in the vicinity of the fault.

(3) The San Benito gravels are coarse throughout, and it is possible that they were deposited no farther southwest than the Bear Valley fault. However, it seems unlikely that the fault formed a barrier to deposition toward the southwest, because the Monterey on that side is no more resistant than the Franciscan on the northeast, and does not form a topographic cliff against which the gravels might be deposited.

A boundary between rocks as different in character as granite and the Franciscan would naturally form a zone of weakness, which undoubtedly explains the series of successive movements along the Bear Valley fault. The San Andreas fault, which formed later, roughly followed this zone of weakness, but being a vertical shear-fault, it developed a straighter course. It cut across many of the irregularities of the Bear Valley fault, leaving the latter as much as half a mile distant. Since the Bear Valley fault dips toward the San Andreas, the San Andreas must cut across or join the Bear Valley fault at depth. Because the Bear Valley fault marks the original line of weakness along which the San Andreas developed in this part of its course, it

might be called the "ancestral San Andreas fault." This ancestral San Andreas fault should be clearly distinguished from the San Andreas fault proper, however, because of its different type of fault-surface, different type of movement, different age and history, and because it probably developed in response to a different set of conditions from that which produced the San Andreas fault.

San Benito Fault Zone and Adjacent Area

The most interesting and complex structural features of the San Benito quadrangle occur along the San Benito fault zone, and in the belt between this fault and the San Andreas fault zone. In order to delineate the structure of this belt, block diagrams have been constructed which represent an area 13½ miles long and 4 miles wide and which show practically the whole extent of the San Andreas and San Benito fault zones within the quadrangle (see fig. 9). Two large blocks give a bird's-eye view of the entire area, and 20 smaller blocks show cross-sections made at intervals of less than half a mile to slightly more than a mile, depending upon the relative complexity and amount of variation along the strike. These sections are numbered from 1 to 20, starting at the southeast end, and will be referred to below by number.

The belt lying between the San Andreas and San Benito fault zones averages 2 miles in width. It consists of Franciscan, Santa Margarita, and Etchegoin strata which are tightly folded, overturned, and faulted. In its simplest aspects in the northwest part of the area, the belt may be said to represent a faulted syncline bordered on the northeast by a faulted anticline overturned toward the southwest (sections 14 to 17, fig. 9). In both directions along the strike, however, other faults enter the picture and the syncline loses its identity, although the faulted anticline, represented by the San Benito fault zone, continues.

The San Benito fault zone is the most important thrust-fault in the San Benito quadrangle. It may be traced for a distance of 14 miles in the quadrangle, and continues to the southeast through the Metz and Priest Valley quadrangles, where it was traced by Mielenz (39, p. 255) at least as far as Hernandez Valley, an additional 14 miles. It is called a fault zone because in places it consists of several closely associated branch faults.

The San Benito is a thrust-fault dipping 50° to 70° NE. Its average strike is N. 45° W. Franciscan and Cretaceous on the northeast have been thrust over Etchegoin on the southwest. The Etchegoin sediments have been overturned from 50° to 65° throughout most of the length of the fault. The belt of overturned Etchegoin sediments averages ½-mile to ¾-mile in width. Clear evidence of overturning was established by determining the top side of the strata by means of cross-bedding, graded bedding, and position of echinoids. In general the basal red beds of the Etchegoin occur immediately adjacent to the fault on its southwest side. These red beds form an important "key" horizon, which was found exceedingly useful in working out the structure of this area.

The main thrust-fault of the San Benito fault zone evidently developed along an overturned anticline. For the most part it broke along the crest of the anticline, but in at least three places it broke slightly in back of the crest and left remnants of the original anticline

standing in front of (southwest of) the fault. (See sections 2, 14, and 16, fig. 9).

The main thrust-fault has one or more branches in parts of the area. Some of these branches dip toward the main fault, and have displacements in the opposite direction; that is, they dip to the southwest, and the southwest is the upthrown side. (See sections 5 to 7 and 15 to 18, fig 9). These may actually be later faults which have cut the San Benito fault, rather than branches. In any event they show evidence of late movement, since they displace the San Benito gravels, whereas the major thrusting occurred prior to deposition of the gravels. In places Franciscan serpentine has been squeezed up along both the main and the branch faults.

The San Benito fault zone dies out to the northwest in one of these branches or later faults with a southwest dip. (See sections 18, 19, and 20, fig. 9). To the northwest, overturning of the Etchegoin ceases, and the strata assume a fairly gentle dip toward the southwest. The dying out of the fault is well exposed in the small canyon in the W. ½ sec. 9, T. 15 S., R. 7 E., M. D. In the bottom of the canyon the Etchegoin is overturned 60° to 80° NE., but on the northwest canyon wall the strata are vertical; at the top of the hill they assume a normal dip of about 25° SW.

The major thrusting along the San Benito fault zone occurred after Etchegoin time (middle Pliocene), but before deposition of the San Benito gravels (Plio-Pleistocene). It may thus be closely dated as upper Pliocene. In places there seems to have been reversal of movement in the Pleistocene or Recent, down-dropping the San Benito gravels on the northeast side of the fault (see section 11, fig. 9). This is analogous to reversals of movement along the Bear Valley and Bradford faults. The thrusting must have occurred before deposition of the gravels; otherwise they should have been eroded away from the northeast side of the fault.

Pine Rock Fault Zone

The Pine Rock fault zone lies approximately midway between the San Andreas and San Benito fault zones. It is named for Pine Rock, southeast of the mouth of Sulphur Creek. It follows the course of the San Benito River southeast of Sulphur Creek, and here little can be adduced as to its nature since it is generally buried by alluvium. Its presence is, however, demonstrated by the relations of the beds on either side of the river; on the northeast side are Etchegoin beds overturned toward the northeast; on the southwest side the Santa Margarita dips southwest. Evidently the northeast side has been downthrown (see sections 1 to 6, fig. 9). Two miles east of San Benito the fault is exposed; here it consists of two branches in each of which the Etchegoin is stepped down on the northeast side (see section 1, fig. 9). Farther northwest a splinter of Jacalitos occurs between two branches of the fault (see sections 3 and 4, fig. 9).

Northwest of Sulphur Creek a branch of the Pine Rock fault zone swings to the west (strike N. 65° W.) and has a gentle dip of 40° NE. A thin belt of serpentine has been squeezed up along the fault zone, bounded by Etchegoin on both sides (sections 8 to 11, fig. 9). Another branch, or perhaps a later fault, continues to the northwest, down-

dropping the San Benito gravels on the southwest side (sections 11 to 20, fig. 9).

Paicines Fault

The Paicines fault occurs just northeast of the San Benito fault zone in the western part of the San Benito quadrangle (northeasternmost fault shown on sections 15 to 20, fig. 9). It is, however, of quite different character from the faults of the San Benito zone. It may be traced for 5 miles in the San Benito quadrangle and continues at least 4 miles farther through the Gonzales quadrangle. It passes through the large sag pond enlarged into a reservoir a quarter of a mile south of Paicines, after which it is named.

The Paicines, the only fault in this region at all comparable in nature to the San Andreas fault, possesses the following similar characteristics: (1) the fault plane is vertical; (2) it shows topographic evidence of recent movement by sag ponds, troughs, and scarps; (3) it shows evidence of horizontal displacement by stream offsets (though the amount of displacement is much less than along the San Andreas), and it lacks any appreciable vertical displacement.

The Paicines fault lies in the San Benito gravels throughout its extent in the San Benito quadrangle, but it may readily be traced by topographic evidence. It is generally marked by a straight, narrow trough, bounded by small scarps on one or both sides. It is the only fault, other than the San Andreas, that appears clearly on the aerial photographs.

The fault-plane itself is well exposed in the small canyon along the township line between sec. 32, T. 14 S., R. 7 E., M. D., and sec. 5, T. 15 S., R. 7 E., M. D. The San Benito gravels have clearly been cut by the fault; on the southwest side they dip 20° W.; on the northeast side they show an abrupt right angle difference in strike, and dip 10° N. The relative vertical displacement is not clear, however, and must be slight to allow the gravels to occur on both sides of the fault.

The Paicines fault lies just 1¾ to 2 miles northeast of the San Andreas and closely parallels it in trend (average strike N. 42° W.). Stream offsets show that the southwest side of the fault has moved relatively northwest, as in the San Andreas fault, the possible displacement being 200 or 300 feet. The Paicines and San Andreas faults have undoubtedly developed in response to the same forces. They are the only faults in this area which may be considered "active."

Bradford and Browns Valley Faults

The Bradford fault forms the contact between the Franciscan and Panoche along the north side of the Call Mountains. It is named for the Bradford mine, which is located close to its course three-quarters of a mile southeast of Tres Pinos Creek. The fault may be traced for a distance of 6 miles. It leaves the Franciscan-Panoche contact toward the east, passing into the Franciscan, where its presence is shown by a zone of anomalous strikes. To the west it disappears in the San Benito gravels. The general trend is N. 60° W.

The Bradford fault is a thrust-fault, the fault surface dipping 60° to 80° NE. Franciscan on the northeast has been thrust over Panoche

on the southwest. The thrusting occurred before deposition of the San Benito gravels, and is probably of upper Pliocene age.

The most interesting feature of the fault is the evidence of reversal of movement after deposition of the San Benito gravels. At Vasquez Rock, a quarter of a mile north of Tres Pinos Creek, the San Benito gravels have been downthrown on the northeast side of the fault, upthrown and locally eroded away from the southwest side. The gravels have been displaced 300 feet, in a direction opposite to that in which the Franciscan was thrust over the Panoche. (See fig. 7). This movement took place in the Pleistocene or Recent.

The Franciscan-Panoche contact in the northwest part of the quadrangle is formed by the Browns Valley fault. The fault surface dips about 80 degrees to the northeast, from which side Franciscan has been thrust over the Panoche. The fault disappears to the southeast beneath the San Benito gravels. The entire displacement along this fault appears to have occurred prior to deposition of the San Benito gravels.

Butts Ranch Syncline

The Butts Ranch syncline is the most prominent folded structure occurring in the San Benito quadrangle. It is part of a persistent synclinal axis which extends 25 miles to the southeast through Pimental Canyon into the Vallecitos. The syncline is a rather broad open fold in the Vallecitos (Anderson and Pack 15, plate I), but becomes progressively more highly compressed toward the west. In the San Benito quadrangle the dips on the synclinal flanks are rarely less than 60° and are often close to vertical or are overturned. The syncline is cut by a number of small transverse faults, and a longitudinal fault has repeated some of the section on the northeast side.

The syncline has an average strike of N. 65° W. in the San Benito quadrangle. This trend is closer to east-west than those of the structures between the San Andreas and San Benito fault zones, and is believed to follow roughly the course of an Eocene and Miocene seaway which ran obliquely across the present trend of the Coast Ranges.

The Butts Ranch syncline is overlapped to the northwest by the San Benito gravels, and in part by the Etchegoin group. The axis is buried west of the course of Salt Creek. It may continue beneath the San Benito gravels and connect with a syncline found in the Eocene Tres Pinos formation north of Paicines in the Gonzales quadrangle, but this is conjectural.

The most important bit of evidence concerning the age of folding of the Butts Ranch syncline is the overlap of the Etchegoin group onto the syncline near the head of Salt Creek. Here nearly flat-lying beds carrying abundant Etchegoin fossils rest upon the upturned edges of the syncline with an angular discordance of as much as 90° (see fig. 8). The syncline was folded before deposition of the Etchegoin, in other words, before the middle Pliocene (since the fossils in this area are of restricted Etchegoin, middle Pliocene, age; not Jacalitos or San Joaquin). The youngest formation folded in the syncline is the Temblor upper sandstone, middle Miocene; which places the time of folding between the middle Miocene and middle Pliocene. Although the folding could conceivably have occurred at nearly any time during that

nterval, three main possibilities suggest themselves: (1) post-Temblor, re-Santa Margarita; (2) post-Santa Margarita, pre-Jacalitos; (3) ost-Jacalitos, pre-Etchegoin.

Of these the first possibility seems most likely to the writer, that s, between the middle and upper Miocene. This was the time of reatest shift in distribution of Tertiary deposits in this region.

tructure of San Benito Gravels

The main belt of San Benito gravels, lying between the San Benito ault zone and Tres Pinos Creek, is folded into a broad, gentle syncline, lunging toward the northwest. The synclinal axis strikes about N. 5° W. It extends from Salt Creek northwestward beyond the limits of he quadrangle near Paicines. The inward dips on the flanks and along he plunge of the syncline average 10° to 20°. Higher dips of as much s 60° occur only adjacent to faults. This syncline forms a rough orthwestward continuation of the much more highly folded underlying Butts Ranch syncline, and may be an expression of later, more gentle olding of the older syncline.

A small northeast-trending fault cuts the gravels just south of Cottonwood School, upturning them nearly 90° on the northwest side. ust north of Tres Pinos Creek, west of the Elkhorn Ranch, the forma- ion is traversed by a northwest-trending fault.

The fairly gentle folding of the San Benito gravels stands in sharp ontrast to the strong folding of the underlying rocks, such as those of he Butts Ranch syncline, the Franciscan north of Tres Pinos Creek, he overturned Etchegoin of the San Benito River area, and the Panoche of the Browns Valley area. In the last-named locality the San Benito gravels have a uniform dip of 6° to 8° S. over the vertical dges of the Panoche.

tructure of Franciscan

The main belt of Franciscan in the San Benito quadrangle is olded into a syncline or synclinorium, herein called the Tres Pinos yncline, whose axis runs roughly east-west just north of Tres Pinos Creek. The folding is not so strong as might be expected, the dips veraging not more than 40° to 50°. In places the axis is fairly sharp, ut elsewhere there are several subsidiary axes. On the south side of he structure a considerable amount of wrinkling occurs as the Brad- ord fault is approached. In the headwaters of Las Aguilas Creek in he northeastern part of the quadrangle the structure loses its identity nd possibly merges into an anticlinorium lying to the north. How- ver, the very poor exposures in this region of the first-cycle mature alleys make interpretation of the structure difficult. The synclinal xis is best exposed in Sulphuritos Creek and the area just to the east. An interesting feature is its extension through a belt of glaucophane chist in Willow Springs Creek. The planes of schistosity, which are arallel to the original bedding of the sediments, reflect the synclinal olding as do the unmetamorphosed sediments on either side.

In many places in the Franciscan, northeast strikes occur locally, ften closely adjacent to the more normal east or northwest strikes. Although in places these may be due to faulting, they more commonly

seem to represent actual wrinkles in the structure. They may be remnants of an earlier folding trending northeast, upon which has been superimposed the later northwest-trending folding seen in the younger Coast Range formations. The general eastward trend of the synclinorium in the Franciscan of this area probably represents an earlier period of folding than that of the San Benito River area. The structure may have formed at the same time as the Butts Ranch syncline.

Gabilan Range

The Gabilan Range, composed of a small to moderate thickness of sediments and volcanics resting on a granite basement, has been deformed chiefly by block faulting. The faults trend in various directions, mainly north, northwest, and northeast.

The most important fault is the Pinnacles fault, which has a northward trend. It is a normal fault, dipping 60° to 70° E . Miocene volcanics and sediments have been downdropped on the east; granite upthrown on the west. This fault may be traced for a distance of 6 miles within the quadrangle.

The Chalone Creek fault was mapped and named by Andrews (36, p. 30) in the Metz quadrangle, and it extends about 1½ miles into the San Benito quadrangle. It trends N. 30° W. Monterey sediments on the east side have been downdropped against the older Miocene volcanics on the west. The dip of the fault plane is not apparent.

The only important folds in the Gabilan Range are some small synclines in the Monterey sediments just southwest of the Bear Valley fault and San Andreas fault zone. One of these occurs near the southern edge of the quadrangle, with dips of about 70° on the two flanks. Two miles southeast of Live Oak School is a much gentler syncline with inward dips of about 10°.

Between Chalone Creek and Bickmore Canyon the Monterey strata are tilted at angles of 25° to 35° NW. In fault contact with this belt farther east (between Chalone Creek and Bear Valley) is a broad expanse of Monterey sediments dipping about 10° S.

The granite in the southwestern part of the San Benito quadrangle is cut by a series of middle Miocene rhyolite dikes, whose pattern gives some indication of the Miocene structure of that region. The dikes have been emplaced along fractures trending in general N. 30° W., and dipping 55° to 65° NE. A very few small dikes have some other directional trend. The longest continuous dikes are about 2 miles in length. The fractures along which the dikes are emplaced are presumed to have been normal faults.

STRUCTURAL HISTORY

Pre-Miocene Structure

The earliest structural event of which we have any record was the division of the region into two provinces with separate basement rocks —the Gabilan Range with a granite basement, and the Diablo Range with a Franciscan basement. The division occurred by movement along the Bear Valley fault, the southwest side having been relatively upthrown and the Franciscan eroded from the granite basement. The fault movement was of a normal type.

The time of first movement along the Bear Valley fault can be dated in the San Benito quadrangle only as pre-Monterey, but has been dated elsewhere as post-Cretaceous, pre-Temblor, and is believed to be Eocene by Taliaferro (41, p. 154).

Gentle folding of pre-Domengine, post-Capay (middle Eocene) age is recorded locally to the east in the Panoche quadrangle, and is indicated to some extent in the San Benito quadrangle by overlapping of the Domengine sandstone onto various Cretaceous and middle Eocene formations.

Middle Miocene Faulting in Gabilan Range

The Gabilan Range was cut during the middle Miocene by a series of normal faults or fissures, along which rose abundant rhyolite dikes. These have a general strike of N. 30° W., and dip toward the northeast.

Middle Miocene-Middle Pliocene Folding

The first important period of folding involved the Butts Ranch syncline. This may be dated definitely only as occurring sometime between the middle Miocene and middle Pliocene, but it seems most likely that it occurred between the middle and upper Miocene. The structural trend of the syncline is more nearly eastward than that of later features. The development of the Tres Pinos syncline in the Franciscan, also having a general eastward trend, may have occurred at the same time.

Upper Pliocene Deformation

The strongest deformation occurred in the upper Pliocene. This produced intense overturning and thrusting along the San Benito fault zone. Thrusting along the Bradford, Browns Valley, and Bear Valley faults probably occurred at the same time.

Late Pleistocene and Recent Deformation

The San Benito gravels (Plio-Pleistocene) have been gently folded into a broad, plunging syncline, and faulted in places. The faulting has been in part by reversals of movement along earlier thrust-faults, as along the Bradford, Bear Valley, and probably also the San Benito fault zone.

Active Faults

The only faults showing topographic evidence of recent movement are the San Andreas and Paicines faults. Both show evidence of horizontal displacement. No antiquity (older than Pleistocene) can be demonstrated for the San Andreas fault in its present form, although in part it follows the course of the Bear Valley fault, whose first movement was pre-Miocene, probably Eocene.

Summary of Structural History

The various periods of deformation represented in the San Benito quadrangle are summarized in the accompanying table.

It should be clear from this survey of structural history that the deformation of the Coast Ranges did not occur in a single period (e.g. Pleistocene) as would be implied by such a term as "Pasadenan"

orogeny (Stille 36, p. 867). The "Pasadenan" orogeny in the San Benito quadrangle is represented mainly by gentle folding and reversals of movement on old thrust faults. The Coast Ranges have undergone a complex history of repeated deformations which have not affected all parts of the ranges equally. In particular, the earlier deformations died out toward the eastern margin of the range, along the San Joaquin Valley, which, unfortunately, has been the most studied portion. Here disconformities are described which may be represented elsewhere by profound angular discordances.

PERIODS OF DEFORMATION IN SAN BENITO QUADRANGLE

Age	Type of deformation	Area affected
Eocene ? (post-Cretaceous, pre-Temblor)	Normal faulting along Bear Valley fault. Gabilan Range uplifted.	Gabilan Range.
Middle Eocene (post-Capay, pre-Domengine)	Gentle folding.	Butts Ranch syncline.
Middle Miocene	Normal faulting; faults intruded by rhyolite dikes.	Gabilan Range.
Between middle and upper Miocene ? (post-Temblor, pre-Etchegoin)	Folding.	Butts Ranch syncline; perhaps also main Franciscan area.
Upper Pliocene (post-Etchegoin, pre-San Benito)	Strong folding, overturning, thrust-faulting.	Entire area; most striking results in San Benito River area.
Late Pleistocene or Recent (post-San Benito)	Gentle folding; reversals of movement along upper Pliocene thrust faults.	Probably entire area; results shown in areas covered by San Benito gravels.
Recent ("Active")	Horizontal displacement along San Andreas and Paicines faults.	San Benito River area.

Even earlier disturbances than those found in the San Benito region occur in other parts of the Coast Ranges; for example, a strong Upper Cretaceous orogeny is reported by Taliaferro (41, pp. 131-132) from the Santa Lucia Range. We might generalize that over the Coast Ranges as a whole the last two orogenies—upper Pliocene and Pleistocene—have been the most severe; in the particular area studied, the upper Pliocene deformation was most important.

PALEOGEOGRAPHY

Any discussion of the paleogeography of a region as limited in size as a quadrangle may seem futile, but the San Benito quadrangle is so located as to throw considerable light upon the paleogeography of a fairly large surrounding area. In particular, it shows evidence of at least two separate Tertiary seaways connecting the San Joaquin Valley with the coast.

The name "San Benito trough" has been given to a persistent Tertiary seaway connecting the San Joaquin Valley with the coast

across the San Benito region (Clark 30; Reed 38). The term actually covers two separate seaways, however, for the Eocene and Miocene connection was through the Butts Ranch and Vallecitos synclines, whereas the Pliocene seaway had a different course to the southeast through Waltham Canyon. In figures 10 and 11 the term "Butts Ranch-Vallecitos trough" is used for the Eocene and Miocene seaway; "San Benito-Waltham Canyon trough" for the Pliocene seaway.

Jurassic

The oldest sedimentary formation in the area (except for the Gabilan limestone, about which little may be said) is the Franciscan, Upper Jurassic. Although this is now limited to the northeast side of the Bear Valley fault, it does not seem likely that such was always the case. Reed (33, p. 78) has postulated that "Salinia", lying southwest of the San Andreas fault zone, was never covered by the Franciscan. But this seems untenable because of the absence of shoreline deposits in the Franciscan immediately adjacent to the boundary of "Salinia." It is possible, however, that the Gabilan region formed a bank or shelf during the Jurassic over which the Franciscan deposits were relatively thin.

Cretaceous

There is some question as to the extent of the Cretaceous deposits. They may have covered the entire region, or they may have been deposited only in the Diablo Range, where they are now found. At the present time they are not exposed close enough to the Gabilan Range to determine any changes in facies which might indicate shoreline conditions in that direction.

Eocene

The Eocene seas were evidently much more restricted than those of earlier periods. In the heart of the Diablo Range, west of the San Joaquin Valley, their deposits are now found only in the oblique belt represented by the Butts Ranch and Vallecitos synclines—interruptedly continuing to the northwest near the town of Tres Pinos. It seems likely that this represents a strait or seaway connecting the San Joaquin Valley with the Coast during Eocene time.

The minimum extent of this seaway is shown in figure 10 which represents the present distribution of Eocene deposits (exposed or known to be buried by younger deposits) in the area between Hollister and Coalinga. Of course the original distribution of the sea was greater than this—how much greater is difficult to say. It seems doubtful if Eocene deposits covered the Gabilan Range. As already pointed out, this range was uplifted some time between the Cretaceous and middle Miocene, and because of the great amount of erosion which occurred it seems probable that the uplift was Eocene rather than later.

Middle Miocene

Distribution of middle Miocene (Temblor) deposits is similar to the distribution of Eocene deposits, being confined mainly to the Butts Ranch-Vallecitos trough. However, the sea was apparently somewhat

broader for it transgressed the Eocene boundaries to the north into the Panoche Valley, and to the south to the vicinity of Red Mountain and the Monterey coal mine, in the Priest Valley quadrangle (Mielenz 39, p. 154).

Upper Miocene

The greatest shift in distribution of seas in this region apparently came between the middle and upper Miocene. The Santa Margarita formation (upper Miocene) is confined to the San Benito-Waltham Canyon trough, running along the San Benito River in this quadrangle and extending southeastward through Waltham Canyon to the San Joaquin Valley. It extends northwestward to the Sargent district, northwest of Hollister.

Some consideration should be given to the Monterey deposits on the east flank of the Gabilan Range. It is difficult to fit them into the paleogeographic picture because of the uncertainty of exact age equivalence with the formations to the east. They may actually be equivalent in time to part or all of the Santa Margarita, despite the great difference in lithologic facies. If so, the eastern extent of this sea would be the same as for the Santa Margarita. But if the Monterey is older, the eastern extent must remain unknown. The western shoreline we can delineate with more certainty, because evidence of it is actually preserved in the sediments on the east side of the Gabilan Range. The gradation of diatomaceous shales toward the west into extremely coarse conglomerates containing granitic and rhyolitic debris has already been mentioned. Evidently the main bulk of the Gabilan Range formed an island at this time, since it contributed so much detrital material.

Pliocene

More information is available concerning distribution of the Pliocene seas than for any of the preceding periods, because of more accurate knowledge concerning directions of thinning and thickening of the sediments, and the occurrence of both marine and nonmarine facies in various places. Figure 11 shows the present distribution of Pliocene deposits between Hollister and Coalinga (including areas in which the deposits are known with reasonable certainty to have been buried or removed).

The main area of Pliocene deposition is here called the San Benito-Waltham Canyon trough, a narrow belt, 2 to 3 miles wide, running southeastward from the Sargent district, through the San Benito River area and Waltham Canyon to the San Joaquin Valley. This is the area of maximum thickness of Pliocene deposits and was evidently a sinking basin, because the thicknesses range from more than 3000 feet in the San Benito area to as much as 8000 feet in Waltham Canyon. In places the sea spread out to either side of this main trough, forming marginal deposits with thicknesses of less than 1000 feet. Examples are the Sulphur Creek area, Hernandez Valley, the White Creek syncline, and the southern extension of the Gabilan Range, called the Gabilan Mesa. In the Sulphur Creek area these marginal deposits show a considerable coarsening away from the main trough, which, combined with a marked thinning of the deposits, indicates a shoreline not far to the east.

Although the southwestern boundary of present distribution of Pliocene deposits in the San Benito region is the San Andreas fault, it is not thought that this was the boundary of the seaway, because of the absence of shoreline deposits immediately adjacent to the fault. The sea undoubtedly extended some distance southwest of the fault, but just how far cannot be determined.

The Pliocene left the earlier Butts Ranch-Vallecitos trough "high and dry" for only non-marine red-bed deposits are found in the Vallecitos syncline, extending to the northwest up Pimental Canyon.

The San Benito-Waltham Canyon trough has a more southeasterly trend than the earlier seaway, having an average strike of N. 45° W., whereas the Butts Ranch-Vallecitos trough, where it cuts obliquely across the range, strikes about N. 70° W. The two seaways are parallel and possibly more or less coextensive from a few miles northwest of Butts Ranch to the vicinity of Tres Pinos, where they are blanketed by Plio-Pleistocene deposits.

SUMMARY OF GEOLOGIC HISTORY

Sometime before the Jurassic, possibly as far back as the pre-Cambrian, the Gabilan limestone was deposited in the Gabilan Range. This was metamorphosed and intruded by the Santa Lucia granite.

In the Upper Jurassic a thick sequence of terrigenous sediments (Franciscan group) was deposited. These sediments, dominantly arkosic, were probably derived from rapid erosion of a mountain range lying to the west of the present Pacific shoreline. Intercalated with the clastic sediments are pillow basalts and radiolarian cherts, most likely produced by submarine volcanism. The entire sequence was cut by ultrabasic intrusives, altered to serpentine, which pneumatolytically metamorphosed the wall rock locally into glaucophane and actinolite schists.

Deposition, mainly of shales, continued through the Upper Jurassic and Lower Cretaceous to form the Knoxville and Paskenta formations. The land-mass supplying detritus was probably of lower relief than it had been during the Franciscan. The middle Cretaceous Horsetown formation is absent and may never have been deposited in this area. Thick clastic sediments accumulated during the Upper Cretaceous. Consisting dominantly of arkosic sandstones and interbedded shales, these were probably derived by fairly rapid erosion from a granitic land-mass.

Paleocene and early Eocene sediments appear to be absent in this region. However, a complete sequence of middle and upper Eocene sediments is represented. These are sandstones and shales deposited in the Butts Ranch-Vallecitos trough.

The Oligocene and lower Miocene rocks are missing, unless they may be represented by some of the Kreyenhagen and Temblor beds. Middle Miocene sandstones and shales derived largely from erosion of the Franciscan were deposited in the Butts Ranch-Vallecitos trough. Sometime during the Miocene, probably in the middle Miocene, extensive volcanism occurred in the Gabilan Range. Rhyolite and more basic flows were poured out, culminating in explosive eruptions of vulcanian type, which produced thick rhyolitic pyroclastics.

In the upper Miocene thick arkosic sandstones and conglomerates of the Monterey group were deposited on the east flank of the Gabilan Range. These grade from coarse non-marine deposits into marine sediments including diatomaceous shales toward the east. Contemporaneously or later in the upper Miocene littoral Santa Margarita deposits accumulated along the San Benito-Waltham Canyon trough. These were derived mainly from the east, whereas the Monterey sediments were derived entirely from the west.

Pliocene seas then invaded the San Benito-Waltham Canyon trough forming highly fossiliferous littoral deposits corresponding to the Jacalitos, Etchegoin, and probably the San Joaquin formations of the San Joaquin Valley. The upper Pliocene folding and accompanying uplift resulted in Plio-Pleistocene flood-plain deposits which blanketed much of the region.

Following the last Pleistocene folding and uplift, two cycles of erosion ensued, the first reaching a stage of late maturity, the second a stage of late youth or early maturity.

MINERAL RESOURCES

Quicksilver

The *Bradford mine* is located south of Tres Pinos Creek, 25 miles southeast of Hollister, in secs. 3, 4, and 9, T. 15 S., R. 8 E., M. D. Cinnabar occurs in serpentine and silica-carbonate rock along the Bradford fault, which thrusts Franciscan over Panoche to the southwest. The workings are caved, but a diagram is given by Forstner (03, p. 132). An incline shaft followed the contact of the silica-carbonate rock with underlying fault gouge for 200 feet. Down the slope to the north, 160 feet vertically below the collar of the shaft, a tunnel was driven southeast for 535 feet, following the same contact. This tunnel was connected with the shaft by a raise. Forstner (03, p. 133) states: "No ore bodies have been disclosed by this work; however, the serpentine carries some cinnabar throughout." Cinnabar is said to have been discovered here in 1859 during construction of the road up Tres Pinos Creek to the New Idria mine. The production is unknown, but the mine is listed as a small producer on the outline geologic map of California showing locations of quicksilver properties (Jenkins 39). The mine has been idle for a number of years.

The *Cannon mine* is located adjacent to and north of the Bradford along the same belt of silica-carbonate rock, in sec. 4, T. 15 S., R. 8 E., M. D. The workings are caved, but Forstner (03, p. 134) describes them as follows:

> "A drift 130 feet long has been run, with a winze 30 feet deep in the silicified serpentine. At the bottom of the winze is a drift 90 feet long, showing that the serpentine carries some cinnabar, but without disclosing a pay shoot."

The *Butts mine* is located east of Pine Rock in the SW¼ sec. 4, T. 16 S., R. 8 E., M. D. It is 28 miles by road southeast of Hollister. The mine is in brecciated Franciscan sandstone situated in a sliver along the San Benito fault zone. Prior to 1903 a tunnel 300 feet long had been driven, and a shaft 20 feet deep had been sunk (Forstner 03, p. 133). These workings produced a small amount of mercury. Some

other workings a quarter of a mile north were opened during World War I. These workings are now caved, but a description is given by Bradley (18, pp. 101-102) as follows:

"An open cut and tunnel totalling 75 feet, driven some time ago by (Geo.) Kline, in which it is reported that good ore was found, have caved in. A tunnel and open cut totalling 60 feet have been driven above this caved ground and about 20 feet below the outcrop. This has cut diagonally across a chert and sandstone breccia which carries ore for a width of about 18 inches. Cinnabar and metacinnabarite occur in the cementing material of the breccia with a calcite gangue."

The mine has had a small production, but has not been worked in recent years.

The *Lone Star mine* is reported to occur in the Rancho Real de las Aguilas, or McCreary Ranch, 18 miles southeast of Tres Pinos, near Los Muertos Creek. This location is in the main Franciscan area of the San Benito quadrangle. The mine was not seen by the writer, but Bradley (18, p. 107) states:

"A tunnel said to be 800 feet long has been driven. Rock purporting to come from this mine showed a little cinnabar in altered and iron-stained serpentine, but no ore in commercial amount was reported."

Manganese

The *McCreary Ranch mine* is situated north of Antelope Creek in the Rancho Real de las Aguilas or McCreary Ranch, in the S½ sec. 29, T. 14 S., R. 9 E., M. D. The property is leased to R. R. Stephenson, 548 Glenview, Oakland, and was being developed in the early part of 1943. No ore had been shipped as yet, but some had been removed and stockpiled at the mine. Two open cuts 100 feet apart are situated on different horizons of manganese oxide enclosed in Franciscan chert. The chert in turn occurs as lenses bordered by greenstone, but the main rock in the surrounding area is Franciscan sandstone. The chert strikes N. 35° E., and dips 40° NW. The western cut reveals a lens of high-grade manganese oxide ore enclosed in massive white and pale-green chert cut by quartz veinlets and stained by manganese oxide. The ore is chiefly of the hard, blue-black psilomelane type, minutely botryoidal, and somewhat porous. It is accompanied by soft black oxide. The ore contains red hematite stains and a few patches of cellular silica, although the silica content is comparatively low. The ore sorted out on a stockpile at the mine contains over 50 percent manganese. The eastern cut contains small pockets of ore in a massive manganiferous white chert bed enclosed in thin-bedded white and pale-green chert. The massive chert contains films and seams half an inch thick of manganese oxide. It probably contains some bementite or neotocite (hydrous manganese silicates).

Manganese deposits also occur in San Benito County north of the San Benito quadrangle east of Quien Sabe Valley (Bradley et al. 18, pp. 59-61), just east of the quadrangle on the Hannagan Ranch south of Panoche Valley, and south of the quadrangle on the Chambers Ranch in Bitterwater Valley in a sliver of Franciscan chert in the San Andreas fault zone. A prominent lens of Franciscan chert on Cherry Peak, between Los Muertos Creek and Tres Pinos Creek, contains heavy stains and seams of manganese oxide, although a definite orebody has not been exposed.

Chromite

The *Ingalls prospect* is described by Aubury (06, p. 269) as follows:

"Tom Ingalls, Emmett P. O., about fifteen years ago performed some development work on a deposit of chromite, in Sec. 36, T. 14 S., R. 7 E., and it is claimed found a quantity of good ore. Since that time no further work has been done."

The writer is uncertain as to the exact location of this prospect, but it is presumably in one of the small serpentine bodies in the Franciscan glaucophane schist belt which occurs in the southeastern part of sec. 36, northeast of "Emmett Station" on the topographic map (now Elkhorn Ranch).

Gold

Prospecting for gold has been carried on in the Pinnacles National Monument, just south of the San Benito quadrangle. Two tunnels, the Chalone and Defiance, were driven 540 and 400 feet, respectively, in sec. 14, T. 17 S., R. 7 E., M. D. (Bradley and Logan 19, p. 638). Gold is said to be a primary constituent of the Miocene rhyolite which occurs at this locality. Bradley and Logan state:

". . . assays showed gold values of one to five dollars at several places in the (Chalone) tunnel, but no quantity of ore was found. There appeared no way of distinguishing barren from gold-bearing material."

Copper

The *Copper Mountain Mining Company* carried on exploration for copper just south of the San Benito quadrangle and one mile west of the Pinnacles National Monument in sec. 33, T. 16 S., R. 7 E. Several adits and open cuts were excavated in granite containing iron gossan, copper carbonate stains, and chalcopyrite (Laizure 26, p. 233). It is reported that right and title to the ground have been revoked by the Land Office in view of its position controlling the western entrance to the Pinnacles National Monument.

The *Antelope copper mine* is located one mile east of the San Benito quadrangle, east of Antelope Creek, in sec. 4, T. 15 S., R. 9 E., M. D. It was discovered in 1887, and is now owned by H. V. Underwood et al. of Hollister. The mine is in the main Franciscan area of the quadrangle. It was not visited by the writer, but from the description it is judged to be in Franciscan sandstone impregnated with copper carbonate and iron oxide (Laizure 26, pp. 231-232). Early workings consisted of two inclines 400 feet and 100 feet in length. Later another incline was driven for 200 feet; and a winze 10 feet deep was sunk 100 feet from the mouth. The walls of this working are said to be covered with a thin scale of green chalcanthite, hydrous copper sulphate. No copper has been produced from this mine, so far as known, but early in 1943 attempts were under way to have the deposit developed.

Coal

Coal is said to have been worked north of Emmett (now Elkhorn Ranch) in 1878. According to Irelan (88, p. 486), "About five hundred pounds were shipped to England, and there pronounced good jet. . . .". An incline and two tunnels were driven, but these workings have long since caved. The reported locality as shown to the writer by local inhabitants consists of a bed of impure lignite about 6 inches thick enclosed in clay-shale of the San Benito gravels.

Bentonite

Deposits of a plastic clay resembling bentonite, locally called "mineral soap," have been sporadically mined at two localities along Willow Creek: (1) in the Miocene vent tuff area in sec. 33, T. 15 S., R. 7 E.; (2) in a tuffaceous layer in the Pinnacles formation in the N½ sec. 30, T. 15 S., R. 7 E. These deposits are owned by George Melendy. Small open cuts and a short tunnel have been developed. Some of the material has been mined and shipped in recent years, but the exact production is unknown.

Oil and Gas

The oil-bearing formations of the Coalinga and Kettleman Hills districts occur in two belts in the San Benito quadrangle: the Upper Cretaceous, Eocene, and middle Miocene formations in the Butts Ranch-Vallecitos belt, and the upper Miocene and Pliocene beds in the San Benito-Waltham Canyon belt. Favorable structures for the accumulation of petroleum do not appear to be present, however. Both belts are so strongly folded that the dips are for the most part close to vertical or are overturned. Oil has been obtained to the northwest in the Sargent district, and drilling has been carried on to the southeast in the Vallecitos syncline. Wells have been drilled in Topo Valley, south of the quadrangle, in oil seepages in Miocene sediments, but without success. Local inhabitants have told of gas seepages south of Tres Pinos Creek, in an area in which the Cretaceous and Tertiary sediments of the Butts Ranch syncline are overlapped by the Plio-Pleistocene San Benito gravels. The writer could not verify this reported occurrence, however.

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MINERAL EXHIBIT AND STATISTICS

CURRENT NOTES ON EXHIBITS AND STATISTICS

By Henry H. Symons*

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MUSEUM ACQUISITIONS

The Museum of the State Division of Mines possesses an exceptionally fine collection of rocks and minerals of economic and academic value. It ranks among the first five such collections in North America and contains not only specimens of most of the known minerals found in California, but much valuable and interesting material from other states and foreign countries as well.

The exhibit is daily visited by engineers, students, business men, and prospectors, as well as tourists and sightseers. In addition to its practical use in the economic development of California's mineral resources, the collection is a most valuable educational asset to the state and to San Francisco.

Mineral specimens suitable for exhibit purposes are solicited, and their donation will be appreciated by the Division of Mines, as well as by those who utilize the facilities of the collection.

Among the specimens received recently and catalogued for the exhibits are the following:

21112 NEPHRITE JADE. Locality: tideland south of Big Sur, Monterey County, California. Donor: Lawson C. Shaug. March 1943. In case 227.

21113 KYANITE (an aluminum silicate—Al_2SiO_3). Locality: Cope's Bridge, west of Westchester, Pennsylvania. Donor: Geo. R. Cope. January 1943. In case 131.

21114 SCHEELITE coated with a thin film of TUNGSTITE in tactite. Locality: Margarita claim in Sheppard Canyon, Inyo County, California. Donor: Eugene A. Bacchi. January 1943. In case 209.

21115 SCHEELITE in quartz. Locality: Sheep Head claim in Trail Canyon, 18 miles west of Furnace Creek Ranch, Inyo County, California. Donor: Milton L. Knapp. January 1943. In case 209.

21116 TALC. Locality: north end of the Panamints, Inyo County, California. Donor: Death Valley Curly. January 1943. In case 210.

21117 MANGANESE ORE (over 48 percent manganese). Locality: 30 miles south of Winnemucca, Nevada. Donor: William Polkinghorne. February 1943. In case 241.

* Curator and Statistician, Division of Mines. Manuscript submitted for publication May 14, 1943.

21118 ARSENOPYRITE in limestone. Locality: Property of Pacific Limeston Products Company, in Santa Cruz, California. Donor: Fred W. Johnson February 1943. In case 109.

21119 CALIFORNIA JADE (IDOCRASE) with GOLD. Locality: Near Happy Camp Siskiyou County, California. Donor: T. Orchard Lisle. March 1943. I case 616.

21120 WYOMING JADE. Locality: Near Casper, Wyoming. Donor: T. Orchar Lisle. March 1943. In case 616.

21121 CALCITE. Locality: limestone quarry on Rattle Snake Creek, near Auburn Placer County, California. Donor: T. Orchard Lisle. March 1943. In fluor escence case.

21122 CINNABAR. Locality: Polar Star mine near San Simeon, San Luis Obisp County, California. Donor: E. D. Rogers. April 1943. In case 309.

21123 SILVER (native) and GOLD. Locality: Big Seven mine, Neihart, Montana Donor: Henry Croff. April 1943. In case 242.

21124 RUBY SILVER. Locality: Big Seven mine, Neihart, Montana. Donor: Henry Croff. April 1943. In case 242.

21125 SILVER-ZINC ore. Locality: Ripple mine, Neihart, Montana. Donor: Henry Croff. April 1943. In case 242.

21126 LEAD-SILVER ore. Locality: Silver Dike mine, Neihart, Montana. Donor Henry Croff. April 1943. In case 242.

21127 LEAD-ZINC-SILVER ore. Locality: Silver Belt mine, Neihart, Montana Donor: Henry Croff. April 1943. In case 310.

21128 LEAD-ZINC-SILVER ore. Locality: Ingersoll mine, Neihart, Montana Donor: Henry Croff. April 1943. In reserve.

21129 SILVER (brittle silver ore). Locality: Ruth Mary mine, Neihart, Montana Donor: Tony and Carl Faller. April 1943. In case 242.

STATISTICS

The counties of California for some years past have produced more than 50 different mineral substances. Total value of production was estimated at $379,483,000 for 1942.[1]

At present (May 1943) reports from most of the 1942 producers have been received. Data for several substances are now compiled, and are presented herein. Information at hand indicates that there was no commercial production during 1942 of the following: arsenic, bismuth, calcium silicates, fluorspar, mica, nickel, serpentine, shale oil, tin, vanadium, and zircon.

There was a single producer of each of the following: coal, lithia, molybdenum, potash, pyrite, slate, and titanium.

Borates

During the year, there was produced in California a total of 232,833 net tons of borate material, as compared with 278,451 tons for the preceding year. The material shipped during the year included the sodium borates, kernite (rasorite), kramerite from Kern County; also crystallized borax prepared by evaporation of brines at Searles Lake in San Bernardino County and Owens Lake in Inyo County, and a small amount of colemanite from Death Valley, Inyo County.

As the crude ore is not sold as such, but is almost always refined into the borax of commerce before shipping, and since the material varies widely in boric acid content, tonnage has been recalculated on the basis of 40 percent A.B.A. This is approximately the average A.B.A. content of colemanite after calcining, and also of the crystallized borax obtained from evaporation of the lake brines.

Recalculated, the 1942 output totaled 203,716 net tons, valued at $4,929,553, as compared with 224,986 tons worth $4,745,872 for the

[1] Symons, Henry H., Review of California mineral production for 1942: California Div. Mines Rept. 39, pp. 106-107, 1943.

year 1941. This production came from two properties in Inyo County, two in San Bernardino County, and one in Kern County.

Carbon Dioxide

There were two companies producing natural carbon dioxide from wells near Niland, Imperial County, and one from springs near Hopland, Mendocino County, during 1942. The total 1942 production of 193,143 M. cu. ft. of carbon-dioxide gas was converted into 11,921 net tons of dry ice, worth $310,000. In 1941, 138,862 M. cu. ft. of gas made 8,808 tons of dry ice, worth $258,563. The 1942 output was the largest annual yield of commercial carbon dioxide in California.

Cement

During 1942, cement produced in California amounted to 23,306,578 barrels, valued at $35,808,841, f.o.b. plant, of which 12,056,912 barrels came from plants in northern California and 11,249,666 barrels from plants in the southern part of the state. This is the largest annual output in both amount and value ever reported in this state. The 1941 production amounted to 19,531,608 barrels, worth $26,248,694.

Shipments during 1941 were made by 12 plants in 11 counties to the extent of 23,732,414 barrels, valued at $36,964,122 f.o.b. plant, as compared with 19,833,796 barrels, worth $27,219,800 in 1941. During 1942 there were seven operating mills in northern California; one each in Calaveras, Contra Costa, Merced, San Benito, San Mateo, Santa Clara, and Santa Cruz counties, which shipped a total of 12,150,363 barrels of cement; five mills in southern California; two in San Bernardino County; and one each in Kern, Los Angeles, and Riverside counties, which shipped a total of 11,582,051 barrels of cement. There was an average of 2,889 men employed in the mills during the year. The annual capacity of California cement mills, according to the U. S. Bureau of Mines, was 27,540,000 barrels in January 1943, as compared with 26,040,000 barrels for January 1942.

Dolomite

The 1942 output of dolomite in California totaled 142,552 net tons valued at $413,469 and came from two properties in Monterey County and one each in Inyo, Los Angeles, Riverside, San Benito, and Tuolumne counties. In addition, but not included in the above figures, there was a production of dolomite from Tuolumne County that was burnt for lime, and so was included in the lime figures. The 1942 production was the largest annual yield on record in this state. The 1941 production amounted to 22,300 tons, worth $64,595.

The material shipped during the year was utilized for magnesium metal, for steel furnace flux and refractories, stucco dash, terrazzo, kalsomine, poultry grit, artstone, in mineral-wool, and for the manufacture of carbon dioxide.

Gypsum

Shipments of gypsum from California during 1942 amounted to a total of 425,268 net tons, valued at $791,892, and came from five properties in Kern County, and one each in Fresno, Imperial, Monterey, Riverside, and Ventura counties. In addition to the above

figures a considerable amount of gypsum came from Alameda County. This was obtained in a chemical process for reducing magnesium salts from salt-works bittern water with lime; it was not included in the gypsum figures as it was used with lime and magnesite. The 1941 output was the largest annual yield both in amount and value and amounted to 432,784 short tons, worth $854,184.

Iron Ore

Iron ore shipments in California during 1942 totaled 99,092 net tons valued at $371,562 and came from three properties in San Bernardino County and one each in Inyo, Shasta, and Trinity counties. The above was the largest annual output in both amount and value ever reported in this state. The 1941 production was concealed under the "Unapportioned" item so as not to reveal the output of individual operators, and came from a single property each in Inyo, San Bernardino, and Santa Cruz counties.

The ore mined during the year was hematite from San Bernardino County, some of which went to the stockpile at the new steel plant at Fontana (which started operating in December 1942), and magnetite from Inyo and Shasta counties, which was used mostly in heavy concrete for ballast.

Magnesium Salts

There was an output of magnesium salts in California coming from two properties in San Mateo County, and one each in Imperial and San Diego counties, amounting to 6,260 net tons, valued at $642,680, compared with 6,352 tons, worth $654,372 in 1941. The material from Imperial County was magnesium sulphate; from San Diego County magnesium chloride; from San Mateo County magnesium carbonate, hydroxide, oxide, and basic carbonate. Also coming from Alameda County was a tonnage of magnesium hydroxide. The latter was not included in the above totals as it was used as magnesite and therefore will be included in the figures for that substance.

Salt

There was an output of salt in California of 672,324 net tons, valued at $1,922,991, as compared with 434,237 tons, worth $1,180,929 in 1941. The 1942 yield was the largest in amount and was surpassed in value only by that of 1929. There were 16 operating plants during the year; four in San Bernardino County, three in Alameda County, two in Imperial County, and one each in Inyo, Kern, Los Angeles, Modoc, Monterey, Orange, and San Diego counties.

The average value reported by salt producers in California in 1942 was $2.86 per ton, f.o.b. plant, compared with $2.72 in 1941; $2.79 in 1940; $2.75 in 1939; $2.78 in 1938; $2.82 in 1937; $3.08 in 1936; and $3.36 in 1935.

Most of the salt production in California is obtained by evaporation of water of the Pacific Ocean, plants being located on the shores of San Francisco, Monterey, and San Diego bays, and at Long Beach. Additional amounts are derived from lakes and lake beds in the desert regions (in part, rock salt), mainly in Imperial, Kern, and San Bernardino counties; and from evaporation of alkaline lake water in

Modoc County. A small amount of valuable medicinal salts has been obtained by evaporation of the water of Lake Mono, Mono County, and from a mineral spring in Butte County.

Silica

The 1942 output of silica (quartz and glass sand) in California amounted to a total of 193,174 net tons, valued at $692,762 f.o.b. rail shipping point, and came from three properties in San Bernardino County; two in Alameda County; and one each in Kern, Mariposa, Orange, Riverside, and San Diego counties. The above consisted of 102,015 tons of glass sand, worth $432,341, and 91,159 tons of boulder quartz, worth $260,421, and was the largest output in amount and value ever recorded in this state. The 1941 production consisted of 107,679 tons of glass sand and 29,981 tons of boulder quartz or a total of 137,660 tons, worth $514,266.

As vein quartz and silica sand are both used in glass making and as abrasives, production figures for these materials have been combined. Both varieties of silica are utilized to some extent in firebrick manufacture.

Such forms of silica as quartzite, sandstone, flint, tripoli, diatomaceous earth, and gems ("rock crystal," amethyst, and opal), are not included under this heading. Each of these materials has various industrial uses, and so is treated under its own designation.

Soda

The sodium salts produced in California during 1942 included soda ash and trona, from plants at Owens Lake, Inyo County; and soda ash, salt cake, and trona (sesquicarbonate, a double salt of Na_2CO_3 and $NaHCO_3$) from Searles Lake, San Bernardino County. The plant on Dale Lake near Amboy and Searles Lake, San Bernardino County, made shipments of salt cake in 1942. There were no shipments of salt cake (sulphate) from Carrizo Plains, San Luis Obispo County.

Shipments were made in 1942 amounting to a total of 267,723 net tons valued at $3,125,078, as compared with 179,210 tons worth $2,028,718 in 1941. The 1942 output was the largest annual yield as to amount and value and consisted of 145,957 tons of trona and soda ash worth $2,257,660 and 121,766 tons of salt cake worth $867,418.

The soda ash was used mainly in the manufacture of soap, glass, paper, oil refining, sugar refining, and chemicals; and the trona for metallurgical purposes. The salt cake or sodium sulphate was used in the manufacture of paper, glass, and in chemicals.

Talc and Soapstone

The total production of talc and soapstone in California during 1942 amounted to 47,782 net tons valued at $545,509, as compared with 47,935 tons worth $525,396 in 1941. The 1942 output had the largest annual value of any year on record in this state, although the 1941 output slightly passed it in amount. The 1942 output of high-grade talc came from eight properties in Inyo County and three in San Bernardino County; and the soapstone from a single property in El Dorado County.

LABORATORY

ADDITIONS TO BULLETIN 113

By George L. Gary*

Since 1866 many lists have been published showing localities of California minerals. The last one, *Minerals of California,* by Adolf Pabst, was published in 1938 by the Division of Mines as Bulletin No. 113.

It is the intention of the Division of Mines to publish in the quarterly California Journal of Mines and Geology new localities for minerals that are received by the laboratory for determination. So that this information may be accurate, it is requested that all specimens submitted for classification be accompanied by a letter giving the exact location where the material was found.

Following is a current addition to Bulletin 113:

123. **Piedmontite** has been reported from Whitewater, near Palm Springs, Riverside County.

Corrections will also be noted, as well as additions, when called to our attention.

LITHIUM

By George L. Gary*

PHYSICAL PROPERTIES

Spodumene ($LiAlSi_2O_6$), lepidolite ($LiKAl_2F_2Si_3O_9$), and amblygonite ($LiAlFPO_4$) are the principal commercial lithium minerals. Their physical properties are as follows:

Name	Color	Luster	Hardness	Gravity
Spodumene	Greenish-white	Vitreous	6½–7	3.13–3.20
Lepidolite	Rose-lilac	Pearly	2½–4	2.80–3.30
Amblygonite	White	Vitreous	6	3.01–3.09

TESTS

As fusible lithium minerals color the flame a bright crimson, the flame-test method generally is used to detect the presence of lithium in minerals and compounds. The crimson color of the lithium flame is not as persistent as that of strontium. A few drops of barium chloride added to a lithium salt in solution and tested in a flame give, first, the crimson of lithium, then the green of barium, and finally, if strontium is present, the red of strontium. Lithium minerals do not become alkaline upon ignition, as do the strontium minerals. Powdered gypsum is added to the silicates before testing.

* Mineral Technologist, Division of Mines.

OCCURRENCE

Lithium minerals usually are found in pegmatites; lithium is also present in brines, springs, sea water, plant remains and meteorites. In past years lepidolite and amblygonite have been produced in quantities at the Stewart mine at Pala, San Diego County, California. Spodumene, lepidolite, and amblygonite are found in Inyo, Riverside, and San Diego Counties, California (Pabst, A. 38). Crude lithium-sodium phosphate is recovered in substantial quantities as a by-product in the soda operations from Searles Lake, San Bernardino County, California. The crude brines contain as much as 0.032 percent LiCl (Teeple, J. E. 29, p. 18).

PREPARATION

Mining methods are very simple. The crystals (as of spodumene) or masses (as of lepidolite and amblygonite) are handpicked from the broken pegmatite rock. Most of the lepidolite mined and much of the amblygonite occur in solid masses many feet thick and are simply broken down to a size convenient for handling and shipping. No unusual preparation is required before shipment, although pieces of lepidolite containing much quartz and feldspar must be rejected. Where the mineral is to be used directly, as in glass manufacture, all iron minerals must be removed. Where the spodumene is covered with a soft claylike material, this must first be broken off, because it contains almost no lithium. Spodumene ores have been concentrated successfully by froth flotation (Norman and Gieseke 40).

USES

Lithium and its minerals and compounds have many and varied uses in industry. The more important are in the glass, ceramic, chemical, air-conditioning, and metallurgical industries and less extensively in the electrical, pharmaceutical, and optical industries (Houk, L. G. 42; Schaller, W. T. 37, p. 427).

MARKETING

The greater part of lithium-ore production never enters the open market. The chemical manufacturer owns his own mines, the glass manufacturer contracts for his needs, and additional demands are restricted and intermittent. Independent mining operations, therefore, are small and sporadic, and small operators just coming into production find it difficult to guarantee a definite tonnage and quality of ore, yet this they must do to obtain an assured market. Virtually the only method for prospective producers to learn what they can get for their ore is by direct negotiation with buyers. Trade-journal quotations for the various ores are nominal values based upon previous sales of all grades. Price quotations from the Engineering and Mining Journal, March 18, 1943, were as follows:

Spodumene—Per unit Li_2O contained, $5 @ $6 on 6 percent grade, carload lots, North Carolina. Nominal.

Lepidolite—Per ton, $24 @ $25 for ordinary grades, lump, f.o.b. mine.

Amblygonite—Per ton, f.o.b. mines, 8 @ 9 percent Li_2O, $40 @ $50.

Lithium—Per lb., 98 @ 99 percent, 100-lb. lots, $15.

POSSIBLE BUYERS

Associated Metals & Mineral Corporation---40 Rector Street, New York, N. Y.
Bergstrom Trading Company, Inc.---Woolworth Building, New York, N. Y.
Consolidated Feldspar Corporation---Trenton, New Jersey
Corning Glass Works---Corning, New York
Foote Mineral Company---16th & Summer Streets, Philadelphia, Pennsylvania
Harshaw Chemical Company---1945 East 97th Street, Cleveland, Ohio
E. J. Lavino & Company---1528 Walnut Street, Philadelphia, Pennsylvania
Maywood Chemical Company---Maywood, New Jersey
R. T. Vanderbilt Company---230 Park Avenue, New York, N. Y.
Varlacoid Chemical Company---116 Broad Street, New York, N. Y.

REFERENCES

Some of the works listed below give a short bibliography. Books, annuals, and periodicals on lithium may be consulted in the library of the California State Division of Mines where specimens of ore may also be seen.

Houk, Lawrence G.

42 Marketing lithium minerals: U. S. Bur. Mines Inf. Circ. 7225, 14 pp., December 1942.

Norman, James, and Gieseke, E. W.

40 Beneficiation of spodumene rock by froth flotation: Am. Inst. Min. Met. Eng. Tech. Pub. 1161, 1940.

Pabst, Adolf

38 Minerals of California: California Div. Mines Bull. 113, 344 pp., 1938.

Schaller, Waldemar T.

37 Lithium minerals. Industrial minerals and rocks (nonmetallics other than fuels) (Seeley W. Mudd Memorial Series), pp. 427-432, Am. Inst. Min. Met. Eng., 1937.

Teeple, John E.

29 The industrial development of Searles Lake brines, with equilibrium data: Am. Chem. Soc. Mon. Ser., no. 49, 182 pp., 1929.

COMMERCIAL MINERALS OF CALIFORNIA

(Series 1943)

QUARTZ

Compiled by W. B. WINSTON, Laboratory Assistant

Properties. Quartz, SiO_2, is essentially silica or silicon dioxide. It occurs in many different forms. It does not ordinarily show cleavage and most varieties break with a marked conchoidal fracture. It is colorless when pure but found in every color. The luster is vitreous and the mineral may be transparent, translucent or opaque. It has a hardness of 7 and is very resistant. The purest quartz (rock crystal) has a specific gravity of 2.69, other varieties range from 2.5 to 2.8, the mean specific gravity being 2.65 which is that given in the texts. It has one of the highest melting points of all common minerals, 1470° C. One of the outstanding properties of quartz minerals is their chemical

and physical stability. It crystallizes in the rhombohedral system generally in 6 sided (hexagonal) prisms horizontally striated (growth lines) and terminated at each end by 6 sided pyramids. The crystals are often twisted and greatly distorted. They may occur in right- and left-handed crystals; a phenomenon due to a peculiar arrangement of the atoms of which the crystals are built up. This condition has its effect on the optical properties. Twinning in quartz crystals is common. Contact twins are those in which two crystals are in contact one with another, and penetrative twins are those in which two individual crystals are so intergrown that they penetrate one another. Quartz is uniaxial and optically positive. Its mean index of refraction 1.55, its double refraction 0.009, and its dispersion 0.013 are all low. Right-handed crystals rotate the plane of polarization to the right, left-handed crystals to the left. Quartz is the best known example of minerals exhibiting circular polarization; that is, which rotates the plane of polarization of light. Quartz possesses strong piezoelectric properties, which is their capacity for developing electrical charges under pressure and changing dimensions when an electrical charge is applied to them. It also possesses strong pyroelectric properties.

The common form of quartz includes practically all sand, standstone, quartzite, and massive crystalline or vein quartz. Quartz holds a rather prominent place among gem stones, due primarily to extensive use of amethyst and citrine and also rock crystal, and because it is found in great profusion and variety of colors, textures, patterns, and combinations. There is, therefore, a long list of names applied to varieties and subvarieties, of which more than 200 have been listed. The varieties of quartz may be grouped into the following three classes: Crystalline varieties, vitreous, crystallized or crystalline, and more or less transparent. Cryptocrystalline varieties, compact and homogeneous, with a crystalline structure which may be observed with the microscope. Clastic varieties, or those which are made up of fragments of quartz, usually cemented into a coherent mass. These include sand and gravel and the rocks sandstone and quartzite.

The Crystalline Forms of quartz include Rock Crystal which is pure transparent and water-clear quartz, usually but not always well crystallized. Amethyst is a transparent variety of quartz which provides stones of the finest violet color and various shades of purple. It is usually well crystallized. It consists of alternate layers of right- and left-handed quartz, shows Airy's spiral, and breaks with a rippled fracture instead of conchoidal fracture most characteristic of quartz. Smoky Quartz has the physical and chemical properties of clear rock crystal and their crystal forms are identical. It is characterized by a smoky-yellow to dark smoky-brown color due, it is thought, to colorless crystals having been exposed for long periods of time to radium emanations from surrounding rock. Citrine is a light golden-yellow or reddish-yellow variety which probably owes its color to a slight trace of ferric iron. Rose Quartz is rose-red or pinkish, the color being attributed to the inclusions of a small amount of the salts of titanium or manganese. It is commonly massive and is never found as crystals bounded by faces. Milky Quartz is a transparent milk-white and nearly opaque massive variety very widespread in occurrence. The color is due to vast numbers of cavities containing water or liquefied

carbon dioxide, which greatly impairs the transparency of the crystals. Sagenite is a form inclosing hairlike crystals of rutile or other minerals, giving a net-like appearance to the stone, usually named from the included mineral, as Rutilated Quartz or Tourmalinated Quartz, etc. Aventurine is a variety that contains inclusions in the form of scales of some bright mineral as mica or flakes of hematite presenting a spangled appearance when turned in the light. The quartz base may be brown, red, yellow or black, rarely bluish or green. In some unusual quartz types pauses in growth is sometimes shown by cloudy ghost-like images, which suggest 'phantom' forms of earlier crystal growths.

Cryptocrystalline Forms of quartz, or masses which appear to the unaided eye to be amorphous, include Chalcedony, a variety of quartz with a waxy or greasy luster and somewhat splintery fracture, identical with crystalline quartz in chemical composition. Either transparent or translucent occurring in botryoidal, reniform or stalactitic masses. It is composed of microscopic fibers which are optically biaxial. The refractive index and fusing also differ from those of quartz. It is always of secondary origin. There are several forms of chalcedony, all in a variety of dull colors. Chalcedony proper is cream- or milky-colored, and faintly banded. Carnelian or Sard is a clear red chalcedony, pale to deep in shade. Chrysoprase is a translucent variety with a leek- or apple-green color in varying shades, due to nickel oxide. Heliotrope or Bloodstone is essentially a Plasma. It is a feebly translucent bright green to leek-green chalcedony with small spots of blood-red jasper. The green color is due to chlorite, and possibly ferrous salts; the red to hematite. Agate is a variegated chalcedony having definite color, pattern, layers, bands, scenes, or markings of some sort. The colored varieties carry a small amount of metallic salts or oxides, usually iron or manganese and, more rarely, nickel, chromium and copper. The presence of a colloidal solution, with the silica so finely divided as to form a silica gel, is the most recent explanation of the origin of agate. Moss agate is a variety in which the variation in color is due to visible impurities, often of manganese oxide in moss-like patterns. Wood that has been petrified by replacement by clouded agate is known as silicified or agatized wood. Onyx is a layered chalcedony, with layers arranged in parallel planes, hence its use for cameos. Flint is an opaque granular cryptocrystalline variety of quartz usually presenting various dull colors due, it is thought, to organic material. It is brittle, and is composed of an intimate mixture of quartz and opal. Chert is a compact massive rock similar in most properties to flint, but usually light in color. It is considered to have quite a different mode of origin than flint. Jasper is a granular cryptocrystalline quartz, usually colored red from hematite inclusions. It includes in a general way, nearly all varieties of impure, opaque colored cryptocrystalline quartz. Under the microscope it is essentially a very fibrous quartz—a characteristic in which it differs from all other varieties. The members of this group are very numerous, more than seventy different varieties being listed. The color may be red, yellow, brown, green, bluish or black, due to different impurities, as clay, iron, or organic matter. The usual origin of jasper is in a colloidal solution of silica gel.

Clastic Varieties such as sand and gravel are unconsolidated aggregates of highly siliceous, usually quartzose grains from the size of

microscopic particles to boulders. Sands vary greatly according to origin. Sandstone is a rock composed of grains of sand solidified together by some cementing material as silica, iron oxide, calcium carbonate, or clay. QUARTZITE is a metamorphosed sandstone. The cementing material is secondary quartz, giving the stone the appearance of massive quartz. TRIPOLI is a white, finely granular porous form of chalcedonic quartz. PSEUDOMORPHOUS, or 'false forms,' of quartz include the forms quartz has taken through alteration or replacement of crystals of other species—commonly calcite, barite, fluorite and siderite. Silicified wood is one form. TIGER-EYE is a good example of a quartz pseudomorph. It is an asbestos mineral (crocidolite) which has been completely silicified and the original fibers altered to yellow oxide of iron—limonite. In the AMORPHOUS state there are two forms of silica, opal and diatomite; they are not of the quartz family. For more complete description of quartz minerals consult Dana's 'System of Mineralogy.' Also Ref. 4e, 2 and 3.

Tests. Quartz is infusible even on the thinnest edges. When fused with equal volume of sodium carbonate, effervesces and gives a colorless glass; unacted upon by salt of phosphorous. Soluble only in hydrofluoric acid.

In the field, quartz is one of the easiest minerals to determine by sight identification. It may be distinguished by its hardness which is such that it will scratch glass easily, but the mineral can not be scratched with a knife, the steel of which leaves a metallic mark on the stone. By its lack of cleavage, general glass-like appearance, and pronounced shell-like fracture. Most of the imperfections in quartz crystals, as cracks, ghosts, veils, phantoms, needles, and bubbles, can be seen with the unaided eye except optical twinning which is one of the commonest and most serious defects. In twin crystals the individuals have intergrown according to a definite law, and some types of twinning can be observed only in polarized light under the microscope. A laboratory test is required to determine the piezoelectric properties of quartz.

Occurrence. Quartz occurs in nearly every type of rock, igneous, sedimentary, or metamorphic, and is found in formations of all geological ages. Next to the feldspar group it is the most abundant mineral in the earth's crust, free quartz composing fully 12 per cent of the entire lithosphere; and it appears in a greater number of varieties and modes of occurrence than any other mineral. Quartz occurs as a primary and essential constituent of igneous rocks, such as granite, quartz-porphyry, and rhyolite. In pegmatite graphic granite and granophyre it often forms a regular intergrowth with feldspar. It is also a common constituent as regular grains in many gneisses and crystalline schists. By the weathering of silicates silica passes into solution, and quartz is deposited as a secondary product in the cavities of basic igneous rocks. Vein quartz represents the end products of the intrusion and solidification of acidic plutonic igneous rocks, deposition taking place in fractures and fissures in the earth's crust; extensive veins of quartz are also frequent in schistose rocks. Quartz forms the bulk of sands and sandstones. Through weathering of the granites the quartz grains are released, and when these grains are once more cemented by a deposit of

secondary quartz, sandstone and quartzite result. Flint is usually concretinary in form, occurring as pebbles and boulders in other rocks, but sometimes in thick beds. Chert may occur in thick beds, usually brecciated. Among the gem minerals, rock crystal is one of the most abundant. It is found principally in Brazil, Japan, Madagascar, and (small crystals) in New York and Arkansas. It occurs in association with pegmatite, in clefts and crevices in sandstone, and in cavities of limestone, etc. Large cavities have yielded hundreds of tons of crystals, some over 6 ft. long and 2 ft. in diameter, weighing over two tons. Granite rocks and granite pegmatites are favorable places for the formation of large single quartz crystals and groups of crystals. Rock crystals of small dimensions are found in great profusion throughout the world, there is hardly a state in the Union in which fine crystals have not been found. Smoky quartz crystals are most likely to be found associated wth granites and pegmatite dikes. Amethyst occurs usually as druses lining the inner walls of cavities or veins in granite or other igneous rocks, and sometimes lining hollow agate geodes.

All quartz materials, except perhaps quartz crystals of optical grade, are abundantly available in many parts of the United States. In California deposits of vein quartz are plentiful, and many forms of silica occur in commercial quantities, as sand, quartz, quartzite, sandstone and chalcedony. And many of the quartz gem stones are found in the State, such as rose quartz, smoky quartz, and amethyst. Good rock crystal in fine large aggregates has been found in many of the gold mines in Calaveras County, and some good crystal has been reported from 14 counties. For a more complete description of quartz occurrence consult Ref. 4a, c and e. Also 3.

Preparation. Nearly all common quartz is mined from open cuts, quarries, or pit excavations, stripping and excavating methods depending upon the character of deposit and size of workings. The product is usually hauled or shipped to a central grinding plant. At the time of loading the quarried quartz is hand-sorted to eliminate waste rock, and it is also hand-cobbed to some extent. Quartz from pegmatite dikes is usually a by-product in mining feldspar or mica, from which it breaks easily. Preparation at the mine before shipment depends partly on the ultimate use of the product. If going to a pulverizing plant no other preparation or treatment is required than breaking to convenient size for handling. For some special purposes, as acid-tower packing it may be broken to the required size by hand. Metallurgical quartz for flux requires no other preparation than coarse crushing. Abrasive quartz for sandpaper and similar uses is ordinarily prepared by stage crushing and by screening between stages. Crushing and screening is dry, and dry grinding is almost universal. Much of the quartz consumed in the various industries needs to be ground until finely divided. It is nearly always pulverized in tube or pebble mills. The fine pulverizing of rock quartz is sometimes preceded by calcination to make pulverizing easier. Sand is never so treated. Calcining applies especially to quartz used in ceramic bodies. For this purpose the material is ground to pass a 140-mesh screen, and for paint, polishes, and fillers, etc., a 200- or 325-mesh screen. Crystal quartz of the gem varieties requires many different forms of preparation according to intended

use. For detailed discussion of the mining and preparation of silica and sand see Ref. 4a, also c and d. For quartz of the gem varieties consult Ref. 2, and also 4e.

Uses. The factors that determine the adaptability of certain quartz material for a specific use are physical, chemical, and optical. Quartz is extensively used in pottery manufacture to diminish shrinkage of ware in burning. It is also used in the manufacture of wood filler, paints, scouring soap, sandpaper, filters, and tooth powders. Blocks of massive quartz and quartzite are employed as a filler for acid towers, and tube-mill linings. Quartz is also used as a flux in copper smelting and in the manufacture of silicon and ferrosilicon. Much chemical ware is now made of fused quartz. As quartzite, sandstone, and other rock forms, it is used as a building stone and for paving purposes. Many varieties of quartz are used in the cheaper grades of jewelry, but excepting the better grades of amethyst, most quartz material is worth little more than the cost of cutting. Clear rock crystal, however, is used for innumerable ornamental objects such as vases, art figures, crystal balls, etc., and is often cut into beads and fancy shapes and fashioned to resemble the diamond. Rock crystal also furnishes the material for certain glasses and fused silica ware. Selected crystals are employed in optical instruments, for scientific and military use, chiefly as wedges for microscopic work as spectrographic prisms, and for piezoelectric plates which serve to control wave lengths in radio broadcasting. Miscellaneous uses of military interest are in range finders, in instruments used for measuring pressures or detonation in gun barrels or airplane engines, in depth-sounding and direction-finding apparatus, and for sundry precision instruments, including chronometers, seismographs, periscopes, gun sights, and polariscopes. Rock crystal for optical or piezoelectric use must be chemically absolutely pure, and physically of clear optical quality entirely free of color, air and gas bubbles, specks, cracks, seams, feathers, clouds, phantoms, or any other physical flaws. The crystals must be single and optically right or left handed but not twinned. Piezoelectric quartz should also show growth lines on at least two side faces to be able to determine the direction in which the optical axis lies. For radio purposes smoky quartz crystals of a yellow or light smoky color can be used. The minimum size of crystals acceptable by the U. S. government is one inch diameter to two inches in length or about one-quarter of a pound in weight; sizes between 1 and 4 pounds are preferred. Thirty per cent of such crystals must be free of flaws. Although a premium is paid for quartz with crystal faces, unfaced material is also usable. For detailed discussion of the uses of quartz material consult Ref. 4b, also a, c, d, e, and f. Also 1 and 2.

Marketing. Prices quoted by U. S. government agencies, May 1943, on piezoelectric material was $36 a pound for best quality crystals in large sizes, but the average price, since the best grades are very scarce, range from $1 to $10 per pound. Quotations Eng. and Min. Jour., April 1943, were as follows: Quartz Rock crystals—for fusing, all sizes $100 @ $150 per ton. Prisms for piezoelectric and optical use command a substantial premium. Silica per ton, water ground and floated, in bags, f.o.b. Illinois: 325 mesh, $21 @ $40 for 92 to 99½ per cent grades. Dry ground air-floated, 325 mesh, 92 @ 99½

per cent silica $18 @ $30. Glass sand f.o.b. producing plant, $1.25 @ $5 per ton.

Possible Buyers. In the following a few names of possible buyers are given. A more complete list will be furnished by the State Division of Mines. Buyers of high-grade quartz crystals of radio and optical grade in California are: Pacific Radio Crystal Co., 1035 Post St., San Francisco; Karr Engineering Co., Palo Alto; Heintz and Kaufman, Ltd., San Bruno; Electric Products Corp., 950 30th St., Oakland. Silica: Industrial Minerals and Chemical Co., 6th and Gilman St., Berkeley; Kennedy Minerals Co., 2550 East Olympic Blvd., Los Angeles.

The U. S. government will buy quartz crystals of optical and piezoelectric grade as given. Quartz crystals should be sent to W. A. Roche, Quartz Testing Laboratory, U. S. Bureau of Standards, Washington, D. C. If the material sent to the Bureau of Standards is for sale, notice should be sent to R. Gordon Taylor, Miscellaneous Minerals Division, WPB, Washington, D. C., stating that the samples have been sent for testing and grading and that they are offered for sale. Those crystals found acceptable will be paid for by the Metals Reserve Company.

If the samples are sent to the Bureau of Standards merely for testing, H. M. Bannerman, U. S. Geological Survey, Washington, D. C., should be notified in order that they may be inspected by the USGS. If the material submitted does not grade up to specifications and is not marketable, it will be rejected, but will be returned to the shipper if so requested. The procurement Div. of the U. S. Navy Purchasing Office, 315 Montgomery St., San Francisco, will also purchase quartz crystals.

Selected References. Much has been written on quartz minerals and silica material. For more complete descriptions, the following references have been selected; some of these works give an extensive bibliography and most of them are easily obtainable. Books, annuals, and periodicals, as well as mimeographed papers on quartz, may be consulted or obtained at the State Division of Mines, where specimens of rock and gem stones may also be seen.

1. Industrial Minerals and Rocks. Various authors. Quartz, pp. 517-522. Also chapters on Abrasives, Dimension Stone, Granules, and Special Sands, etc., bibliographies. Am. Inst. Min. and Met. Eng., N. Y. 1937.
2. Kraus, E. H. and Slawson, C. B. Gems and Gem Materials, McGraw-Hill Book Co., 1939.
3. Pabst, Adolf. Minerals of California, Calif. State. Div. of Mines, Bull. 113, 1938.
4. U. S. Bur. of Mines (a) W. H. Weigel. Technology and uses of silica and sand, Bull. 266, 1927. (b) R. M. Santmyers. Quartz and Silica, Part I, General Summary, I. C. 6472, 1931. (c) Part II, Quartz, Quartzite, and Sandstone, I. C. 6473, 1943. (d) Part III, Sand and Misc., silicas, I. C. 6474, 1931. (e) I. Aikens, Quartz Gem Stones, I. C. 6561, 1932. (f) Minerals Yearbook, Review of 1940.

LIBRARY

LIBRARY REPORT

By Henry G. Hubbard*

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INTRODUCTION

The library of the Division of Mines contains more than 6,000 selected volumes on mines, mining, and allied subjects. It is also the repository for reports and bulletins of technical departments of Federal and State governments and educational institutions both domestic and foreign. Current copies of newspapers published in the mining centers of the State are also available for reference.

The library and reading room are open to the public during the usual office hours, when the librarian may be freely called upon for all necessary assistance.

PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY AND UNITED STATES BUREAU OF MINES

The library of the Division of Mines has available for public reference the following publications of the United States Geological Survey: Annual Reports, Monographs, Professional Papers, Bulletins, Water-Supply Papers, Mineral Resources, Folios of the Geologic Atlas of the United States (broken file), Maps with Descriptive Text (broken file), Administrative Publications (broken file); and the following publications of the United States Bureau of Mines: Bulletins, Technical Papers, Economic Papers (broken file), Mineral Resources of the United States, Monographs (broken file), Reports of Investigations, Information Circulars.

Reports on California recently received from the Survey and Bureau of Mines include:

United States Geological Survey

Bulletins

931-B Some Quicksilver Prospects in Adjacent Parts of California, Nevada and Oregon.
931-E Tungsten Deposits in the Sierra Nevada near Bishop, California.
931-Q Quicksilver and Antimony Deposits of the Stayton District near Hollister, California.

* Librarian, Division of Mines. Manuscript submitted for publication May 14, 1943.

931-S Manganese Deposits in the Paymaster Mining District, Imperial County, Calif. 1942.
932-A-B-C-D Geophysical Abstracts January-December 1941.
936-D Chromite and Quicksilver Deposits of the Del Puerto area, Stanislaus County, California, 1942.
936-F Quicksilver Deposits of the Parkfield District, California, 1942.
938 Bibilography of North American Geology for 1940 and 1941.
939-A-B Geophysical Abstracts, January-June, 1942.

Water-Supply Papers

930 Surface Water Supply of the Great Basin (California, etc.) 1941.
931 Surface Water Supply of Pacific Slope Basins in California, 1941.

Topographic Maps

Eureka Quadrangle, Humboldt County, California, 1942.
Point Loma Quadrangle, San Diego County, California, 1942.
Reprints (without revision): Cuyamaca; McFarland; Triunfo Pass; and Watts quadrangles.

Professional Papers

197-E Some Standard Thermal Dehydration Curves of Minerals, 1943.
197-F The Action of some Aqueous Solutions on Clays of the Montmorillonite Group. 1943.

United States Bureau of Mines

Bulletins

419 Metal Mining Practice by Jackson & Hedges, 1940.
421 The Joseph A. Holmes Safety Association and its Awards, 1940.
423 Mechanical Shoveling in Underground Metal Mines, 1940.
424 Mineral Industries Survey of the United States—(Part II) Tuolumne and Mariposa Counties, California. 1940. (Continues Mother Lode from Part I in Bulletin 413.)

Technical Papers

608 Safety Factors in Construction and Ventilation, Wawona Vehicular Tunnel, Yosemite Park, California, 1940.
609 Bentonite: Its Properties, Mining, Preparation, and Utilization. 1940.

Reports of Investigations

3673 Stemming in Metal Mines. Progress Report 5. Comparison of Dust and Gases Produced from Different Blasting Charges. 1942.
3678 Use of Wetting Agents in Reducing Dust Produced by Wet Drilling in Basalt. 1943.
3684 Manganese Investigations 20. Ore-Dressing Studies of Eastern Manganese Ores. 1943.

Information Circulars

7202 Marketing Silica (Quartz, Tripoli, Diatomite, etc). 1942.
7222 Use of Diesel Locomotives in Tunnels. 1942.
7224 Directions for Laboratory Mineral Sizing. 1942.
7225 Marketing Lithium Minerals. 1942.
7226 High-Grade Dolomite Deposits in the United States. 1942.
7227 Dolomite-Base Refractories. 1942.
7228 Some Haulage and Hoisting Hazards in Western Mines. 1942.
7233 Monazite Sand by Lawrence G. Houk. 1943.
7234 Marketing Kyanite and Allied Minerals. 1943.

PUBLICATIONS OF STATE SURVEYS

A broken file of mining and geological publications, issued by the organizations listed below, may be consulted in the library of the Division of Mines.

Alabama Geological Survey, University.
Alaska (Territorial Commissioner of Mines), Juneau.
Arizona Bureau of Mines, Tucson.
Arkansas Geological Survey, Little Rock.
Colorado Bureau of Mines, Denver.
Connecticut Geological and Natural History Survey, Hartford.
Florida Department of Conservation, Tallahassee.
Georgia Division of Geology, Atlanta.
Idaho Bureau of Mines and Geology, Moscow.
Illinois Geological Survey, Urbana.
Indiana Division of Geology, Indianapolis.
Iowa Geological Survey, Des Moines.
State Geological Survey of Kansas, Lawrence.
Kentucky Geological Survey, Frankfort.

Louisiana Department of Conservation, New Orleans.
Maine State Geologist, Augusta.
Maryland Geological Survey, Baltimore.
Michigan Geological Survey, Lansing.
Minnesota Geological Survey, Minneapolis.
Mississippi State Geological Survey, University.
Missouri Geological Survey and Water Resources, Rolla.
Montana Bureau of Mines and Geology, Butte.
Nebraska Geological Survey, Lincoln.
Nevada State Bureau of Mines, Reno.
New Jersey Department of Conservation and Development, Trenton.
New Mexico Bureau of Mines and Mineral Resources, Socorro.
New York Science Division, Albany.
North Carolina Geological and Economic Survey, Chapel Hill.
North Dakota Geological Survey, Grand Forks.
Ohio Geological Survey, Columbus.
Oklahoma Geological Survey, Norman.
Oregon State Department of Geology and Mineral Industries, Portland.
Pennsylvania Topographic and Geological Survey, Harrisburg.
South Dakota State Geological Survey, Vermillion.
Tennessee Division of Geology, Nashville.
Texas Bureau of Economic Geology, Austin.
Virginia Geological Survey, University.
Washington State Department of Conservation and Development, Pullman.
West Virginia Geological Survey, Morgantown.
Wisconsin Geological and Natural History Survey, Madison.
Wyoming Geological Survey, Cheyenne.

PUBLICATIONS OF FOREIGN GOVERNMENTS

Publications of the following foreign governments are received and current issues may be consulted in the library. Earlier issues of foreign-language publications have been loaned to the California Academy of Sciences in Golden Gate Park, because of the limited storage space at the Division's offices in the Ferry Building. They may, however, be consulted at the Academy.

Alberta Research Council, Edmonton.
Argentina Direccion General de Minas y Geologica, Buenos Aires.
British Columbia Minister of Mines, Victoria.
British Museum of Natural History, London.
Canada Department of Mines, Ottawa.
Cuerpo de Ingenieros de Minas y Aguas del Peru, Lima.
Geological Service of Minas Geraes, Bella Horizonte, Brazil.
Geological Survey of Scotland.
Instituto Historica e Geographico Rio de Janeiro.
Museo de Historia Natural de Montevideo, Uruguay.
New South Wales Department of Mines, Sydney, Australia.
New Zealand Geological Survey Branch, Wellington.
Nova Scotia Department of Public Works and Mines, Halifax.
Ontario Department of Mines, Toronto, Canada.
Quebec Bureau of Mines, Quebec.
Queensland Department of Mines, Brisbane, Australia.
South Australia Department of Mines, Adelaide.
Transvaal Chamber of Mines, Johannesburg, South Africa.
Western Australia Geological Survey, Perth.

PUBLICATIONS OF FOREIGN AND DOMESTIC SOCIETIES AND EDUCATIONAL INSTITUTIONS

Academia de Ciencias y Artes de Barcelona, Spain.
Academy of Natural Sciences of Philadelphia.
American Association of Petroleum Geologists, Tulsa, Oklahoma.
American Geographical Society of New York.
American Institute of Mining and Metallurgical Engineers, New York.
American Journal of Science, New Haven, Conn.
American Philosophical Society, Philadelphia.
Australian Museum, Sydney.
California Academy of Sciences, San Francisco.
Canadian Institute of Mining and Metallurgy, Montreal.
Carnegie Institution of Washington.
Cleveland Museum of Natural History, Cleveland, Ohio.
Colorado College Publications, Colorado Springs.
Colorado Scientific Society, Denver.
Commonwealth Club, San Francisco.
Economic Geology, Lancaster, Pa.
Field Museum of Natural History, Chicago.

Franklin Institute of the State of Pennsylvania, Lancaster.
Geological Society of America, Columbia University, New York.
Geographical Society of London.
Institution of Mining and Metallurgy, London.
Instituto Geologico de Mexico, Mexico, D. F.
Journal of Geology, Chicago.
Mineralogical Society of America, Menasha, Wisconsin.
Michigan College of Mining and Technology, Houghton.
Mining and Metallurgical Society of America, New York.
Missouri School of Mines and Metallurgy, Rolla.
Museu Nacional, Rio de Janeiro.
National Research Council, Washington, D. C.
New York Academy of Sciences, New York.
New York State Museum, Albany.
Pennsylvania State College, State College.
Philippine Journal of Science, Manila.
Royal Society of South Australia, Adelaide.
Seismological Society of America, Stanford University.
Sierra Club, San Francisco.
Society of Economic Paleontologists and Mineralogists, Fort Worth, Texas.
Southern California Acadamy of Sciences, Los Angeles.
Stanford University, Palo Alto, California.
University of California Publications in Engineering, Geography, and Geology, Berkeley.
University of Harvard, Department of Mineralogy and Petrography, Cambridge, Mass.

CURRENT MAGAZINES

Current issues of the technical magazines listed below are on file in the reading room of the library, and may be consulted.

Asbestos, Philadelphia, Pennsylvania.
Brick and Clay Record, Chicago.
California Journal of Development, San Francisco.
California Mining Journal, Auburn.
California Oil World, Los Angeles.
California Safety News, San Francisco.
Canadian Mining Journal, Gardenvale, Quebec.
Chemical and Metallurgical Engineering, New York City.
Chemical Engineering and Mining Review, Melbourne, Australia.
Chemical Industries, New York City.
Civil Engineering, New York City.
Colorado School of Mines, Golden, Colorado.
Desert, El Centro, California.
Engineering and Mining Journal, New York City.
Fusion Facts, Whittier, California.
Gold, Toronto, Canada.
Grizzly Bear, Los Angeles
Hercules Mixer, Wilmington, Delaware.
Independent Monthly, Tulsa, Oklahoma.
Lubrication, The Texas Co., New York City.
Metals and Alloys, Pittsburgh, Pennsylvania.
Mining and Contracting Review, Salt Lake City.
Mineralogist, Portland, Oregon.
Mining Congress Journal, Washington, D. C.
Mining and Industrial News, San Francisco.
Mining and Geological Journal, Melbourne, Victoria, Australia.
Mining Journal, London.
Mining Journal, Phoenix, Arizona.
Mining and Metallurgy, New York City.
Mining Review, Salt Lake City.
Mining World, Seattle.
Nevada Mining Bulletin, Las Vegas, Nevada.
Nickel Steel Topics, New York City.
Northwest Mining News, Spokane, Washington.
Oil and Gas Journal, Tulsa, Oklahoma.
Oil, Paint and Drug Reporter, New York City.
Oil Weekly, Houston, Texas.
Outdoor Georgia, Atlanta.
Pacific Purchaser, San Francisco.
Pacific Chemical and Metallurgical Industries, San Francisco.
Petroleum World, Los Angeles.
Queensland Government Mining Journal, Brisbane, Australia.
Rock Products, Chicago.
Rocks and Minerals, Peekskill, New York.
Scientific American, New York City.
Southwest Builder and Contractor, Los Angeles.
Stabilizer, Los Angeles.
Standard Oil Bulletin, San Francisco.
Stone, New York City.
Western Mining News, San Francisco.

NEWSPAPERS

Current issues of the following papers are received and kept on file in the library:

Alaska Weekly, Seattle, Washington.
Amador Dispatch, Jackson, California.
Banner, Sonora, California.
Barstow Printer, Barstow, California.
Bridgeport Chronicle-Union, Bridgeport, California.
Calaveras Californian, Angels Camp, California.
Calaveras Prospect, San Andreas, California.
Daily Commercial News, San Francisco, California.
Del Norte Triplicate, Crescent City, California.
Denver Mining Record, Denver, Colorado.
Inyo Independent, Independence, California.
Inyo Register, Bishop, California.
Las Vegas Age, Las Vegas, Nevada.
Livermore Herald, Livermore, California.
Los Angeles Times, Los Angeles. California.
Mariposa Gazette, Mariposa, California.
Mining Press, Reno, Nevada.
Mohave Miner, Kingman, Arizona.
Morning Union, Grass Valley, California.
Mountain Messenger, Downieville, California.
Needles Nugget, Needles, California.
Placer Herald, Auburn, California.
Placerville Times, Placerville, California.
Plumas Independent, Quincy, California.
Randsburg Times, Randsburg, California.
Shasta Courier, Redding, California.
Tehachapi News, Tehachapi, California.
Terra Bella News, Terra Bella, California.
Tuolumne Independent, Sonora, California.
Tuolumne Prospector, Tuolumne, California.
Union Democrat, Sonora, California.
Weekly Trinity Journal, Weaverville, California.
Western Mineral Survey, Salt Lake City, Utah.
Western Sentinel, Etna Mills, California.
Yreka Journal, Yreka, California.

NEW BOOKS

Recent accessions to the library are the following books:

Dampier, Sir William Cecil, A history of science and its relations with philosophy and religion, 3d ed., 574 pp., New York, MacMillan Co., 1942. (John Hays Hammond Public Mining Library.)

DeGolyer, E. (editor), Elements of the Petroleum Industry, Am. Inst. Min. Met. Eng., Seeley W. Mudd Series, 519 pp., 1940. (John Hays Hammond Public Mining Library.)

Fitzhugh, Edward F., Jr., Treasures in the earth, 130 pp., Caldwell, Idaho, The Caxton Printers, Ltd., 1936. (John Hays Hammond Public Mining Library.)

Gustafson, A. F., Ries, H., Guise, C. H. and **Hamilton, W. J., Jr.,** Conservation in the United States, 445 pp., Ithaca, New York, Comstock Publishing Co., Inc., 1940. (F. W. Bradley Memorial Book Fund.)

Holmes, Harry N., Strategic materials and national strength, 106 pp., New York, MacMillan Co., 1942. (John Hays Hammond Public Mining Library.)

Lahee, Frederic H., Field geology, 4th ed., 853 pp., New York, McGraw-Hill Book Co., 1941. (John Hays Hammond Public Mining Library.)

Lawrie, J. P., Methane, its production and utilization, 66 pp., London, Chapman and Hall, Ltd., 1940. (John Hays Hammond Public Mining Library.)

Meinzer, Oscar E. (editor), Physics of the earth—IX—hydrology, 712 pp., New York, McGraw-Hill Book Co., 1942. (John Hays Hammond Public Mining Library.)

Newton, Joseph and **Wilson, Curtis L.,** Metallurgy of copper, 518 pp., New York, John Wiley & Sons, Inc., 1942. (John Hays Hammond Public Mining Library.)

Paine, Paul, Oil property valuation, 204 pp., New York, John Wiley & Sons, Inc., 1942. (John Hays Hammond Public Mining Library.)

von Bernewitz, M. W. (revised by Harry C. Chellson), Handbook for prospectors and operators of small mines, 4th ed., 547 pp., New York, McGraw-Hill Book Co., 1943. (John Hays Hammond Public Mining Library.)

SERVICES OF THE DIVISION OF MINES

The Division of Mines (formerly State Mining Bureau) is maintained for the purpose of assisting in all possible ways in the development of California's mineral resources.

As one means of offering tangible service to the mining public, the State Mineralogist for many years has issued an annual or a biennial report reviewing in detail the mines and mineral deposits of the various counties.

As a progressive step in advancing the interests of the mineral industry, and as permitting earlier distribution to the public, publication of the Annual Report of the State Mineralogist in the form of monthly chapters was begun in January 1922, and continued until March 1923. Owing to a lack of funds for printing this was changed to a quarterly publication, beginning in September 1923. For the same reason, beginning with the January 1924 issue, it became necessary to charge a subscription price. This covers approximately the cost of printing.

Pages are numbered consecutively throughout the year and an index to the complete report is included annually in the closing number.

Beginning with the 1930 issues, the activities and progress of the Geologic Branch are recorded also in these quarterly chapters. The important part that geology plays in the economic development of our mineral resources is further recognized in the change of title from *Mining in California* to California Journal of Mines and Geology, beginning with the January 1933 chapter.

While current activities of all descriptions are covered in these chapters, the practice of issuing from time to time technical reports on special subjects will be continued as well. A list of such reports now available is appended hereto, and the names of new bulletins will be added in the future as they are completed.

The chapters are subject to revision, correction and improvement. Constructive suggestions from the mining public will be gladly received, and are invited.

The one aim of the Division of Mines is to increase its usefulness and to stimulate the intelligent development of the wonderful, latent resources of the State of California.

TYPES OF REPORTS

In general the reports presented in these chapters are grouped into three classes:

1. Mines and mineral resources of a given county or area (describing kind, character, distribution and extent of development).

2. Specific economic and industrial mineral products (listing and describing the resources over the entire State of a given mineral substance, e.g., feldspar).

3. Geological reports on specific areas (recording results and conclusions with maps, derived from field studies; and tied in with economic possibilities and developments).

Reports of District Mining Engineers

In 1919-1920 the Mining Bureau was organized into four main geographical divisions, with the field work delegated to a mining engineer in each district, working out from field offices that were established in Redding, Auburn, San Francisco and Los Angeles, respectively. This move brought the office into closer personal contact with operators, and it has many advantages over former methods of conducting field work, including lower traveling-expense bills for the Bureau's engineers. In 1923 the Redding and Auburn field offices were consolidated and moved to Sacramento.

The Redding office was reestablished in 1928, and the boundaries of each district adjusted. The counties now included in each of the four divisions and the locations of the branch offices are shown on the frontispiece outline map of the State.

Reports of mining activities and development in each district, prepared by the District Engineer, will continue to appear under the proper field division heading.

Special Articles

Detailed technical reports on special subjects, the result of research work or extended field investigations, will continue to be issued as separate bulletins by the Division, as has been the custom in the past.

Shorter and less elaborate technical papers and articles by members of the staff and others are published in each number of California Journal of Mines and Geology.

These special articles cover a wide range of subjects both of historical and current interest; descriptions of new processes, or metallurgical and industrial plants, new mineral occurrences, and interesting geological formations, as well as articles intended to supply practical and timely information on the problems of the prospector and miner, such as the text of new laws and official regulations and notices affecting the mineral industry.

MAIL AND FILES

The Division of Mines maintains, in addition to its correspondence files and the library, a mine file which includes original reports on the various mines and mineral properties of all kinds in California.

During each quarterly period there are several thousand letters received and answered at the San Francisco office alone, covering almost every phase of prospecting, mining and developing mineral deposits, reduction problems, marketing of refined products and mining law. In addition to this, hundreds of oral questions are answered daily, both at the main office and the district offices, for the many inquirers who come in for personal interviews and to consult the files and library.

COMMERCIAL MINERAL NOTES

The producer and consumer of mineral products are mutually dependent upon each other for their prosperity, and one of the most direct aids rendered by this Division to the mining industry in the past has been that of bringing producers and consumers into direct touch with each other.

This work has been carried on largely by correspondence, supplemented by personal consultation. Lists of buyers of all the commercial

minerals produced in California have been made available to producers upon request, and likewise the owners of undeveloped deposits of various minerals, and producers of them, have been made known to those looking for raw mineral products.

When the publication of *Mining in California* was on a monthly basis, current inquiries from buyers and sellers were summarized and lists of mineral products or deposits 'wanted' or 'for sale' included in each issue.

It is important that inquiries of this nature reach the mining public as soon as possible and in order to avoid the delay incident to the present quarterly publication of California Journal of Mines and Geology, these lists are now issued monthly in the form of a mimeographed sheet under the title of 'Commercial Mineral Notes,' and sent to those on the mailing list of California Journal of Mines and Geology.

EMPLOYMENT SERVICE

Following the establishment of the Mining Division branch offices in 1919, a free technical employment service was offered as a mutual aid to mine operators and technical men for the general benefit of the mineral industry.

Briefly summarized, men desiring positions are registered, the cards containing an outline of the applicant's qualifications, position wanted, salary desired, etc., and as notices of 'positions open' are received, the names and addresses of all applicants deemed qualified are sent to the prospective employer for direct negotiations.

Telephone and telegraphic communications are also given immediate attention.

Technical men, or those qualified for supervisory positions, and vacancies of like nature only, are registered, as no attempt will be made to supply mine and mill labor.

Registration cards for the use of both prospective employers and employees may be obtained upon request, and a cordial invitation is extended to the industry to make free use of the facilities afforded. Parties interested should communicate direct with our San Francisco office.

DETERMINATION OF MINERAL SAMPLES

Samples (limited to two at one time) of any mineral found in the State may be sent to the Division of Mines for identification, and the same will be classified free of charge. No samples will be determined if received from points outside the State. It must be understood that no assays, or quantitative determinations will be made. Samples should be in lump form if possible, and marked plainly with name of sender on outside of package, etc. No samples will be received unless delivery charges are prepaid. A letter should accompany sample, giving locality where mineral was found and the nature of the information desired.

Publications of the Division of Mines

PUBLICATIONS OF THE DIVISION OF MINES

During the past sixty-three years, in carrying out the provisions of the organic act creating the former California State Mining Bureau, there have been published many reports, bulletins and maps which go to make up a library of detailed information on the mineral industry of the State, a large part of which could not be duplicated from any other source.

One feature that has added to the popularity of the publications is that many of them have been distributed without cost to the public, and even the more elaborate ones have been sold at a price which barely covers the cost of printing.

Owing to the fact that funds for advancing the work of this department have usually been limited, the reports and bulletins mentioned are printed in limited editions many of which are now entirely exhausted.

Copies of such publications are available for reference, however, in the offices of the Division of Mines, in the Ferry Building, San Francisco; State Building, Los Angeles; State Office Building, Sacramento; Redding; and Division of Oil and Gas at Santa Barbara, Santa Paula, Taft, Bakersfield, Coalinga. They may also be found in many public, private and technical libraries in California and other states and foreign countries.

A catalog of all publications from 1880 to 1917, giving a synopsis of their contents, is issued as Bulletin No. 77.

Publications in stock may be obtained postpaid by addressing the San Francisco, Los Angeles or Sacramento offices and enclosing the requisite amount.

Remittances of stamps in an amount not to exceed 26 cents, currency or coin will be accepted at sender's risk. Payment is preferred in the form of money orders.

Money orders should be made payable to the Division of Mines.

Write for latest revised price list.

NOTE.—The Division of Mines frequently receives requests for some of the early Reports and Bulletins now out of print, and it will be appreciated if parties having such publications and wishing to dispose of them will advise this office.

REPORTS

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
**First Annual Report of the State Mineralogist, 1880, 43 pp. Henry G. Hanks	----
**Second Annual Report of the State Mineralogist, 1882, 514 pp., 4 illustrations, 1 map. Henry G. Hanks	----
**Third Annual Report of the State Mineralogist, 1883, 111 pp., 21 illustrations. Henry G. Hanks	----
**Fourth Annual Report of the State Mineralogist, 1884, 410 pp., 7 illustrations. Henry G. Hanks	----
**Fifth Annual Report of the State Mineralogist, 1885, 234 pp., 15 illustrations, 1 geological map. Henry G. Hanks	----
Sixth Annual Report of the State Mineralogist, Part I, 1886, 145 pp., 3 illustrations, 1 map. Henry G. Hanks—Price $0.75, sales tax $0.02	$0.77
Part II, 1887, 222 pp., 36 illustrations. William Irelan, Jr. Price $0.75, sales tax $0.02	.77
**Seventh Annual Report of the State Mineralogist, 1887, 315 pp. William Irelan, Jr.	----
**Eighth Annual Report of the State Mineralogist, 1888, 948 pp., 122 illustrations. William Irelan, Jr.	----
**Ninth Annual Report of the State Mineralogist, 1889, 352 pp., 57 illustrations, 2 maps. William Irelan, Jr.	----
**Tenth Annual Report of the State Mineralogist, 1890, 983 pp., 179 illustrations, 10 maps. William Irelan, Jr.	----
Eleventh Report (First Biennial) of the State Mineralogist, for the two years ending September 15, 1892, 612 pp., 73 illustrations, 4 maps. William Irelan, Jr.—Price $1.50, sales tax $0.04	1.54
**Twelfth Report (Second Biennial) of the State Mineralogist, for the two years ending September 15, 1894, 541 pp., 101 illustrations, 5 maps. J. J. Crawford	----
**Thirteenth Report (Third Biennial) of the State Mineralogist, for the two years ending September 15, 1896, 726 pp., 93 illustrations, 1 map. J. J. Crawford	----
Chapters of the State Mineralogist's Report, XIV Biennial Period, 1913,-1914, Fletcher Hamilton:	
**Mines and Mineral Resources, Amador, Calaveras and Tuolumne Counties, 172 pp., paper	----
Mines and Mineral Resources, Colusa, Glenn, Lake, Marin, Napa, Solano, Sonoma and Yolo Counties, 208 pp., paper Price $0.50, sales tax $0.01	.51
**Mines and Mineral Resources, Del Norte, Humboldt and Mendocino Counties, 59 pp., paper	----
**Mines and Mineral Resources, Fresno, Kern, Kings, Madera, Mariposa, Merced, San Joaquin and Stanislaus Counties, 220 pp., paper	----
**Mines and Mineral Resources of Imperial and San Diego Counties, 113 pp., paper	----
**Mines and Mineral Resources, Shasta, Siskiyou and Trinity Counties, 180 pp., paper	----
**Fourteenth Report of the State Mineralogist, for the Biennial Period 1913-1914, Fletcher Hamilton, 1915: A General Report on the Mines and Mineral Resources of Amador, Calaveras, Tuolumne, Colusa, Glenn, Lake, Marin, Napa, Solano, Sonoma, Yolo, Del Norte, Humboldt, Mendocino, Fresno, Kern, Kings, Madera, Mariposa, Merced, San Joaquin, Stanislaus, San Diego, Imperial, Shasta, Siskiyou and Trinity Counties, 974 pp., 275 illustrations, cloth	----
Chapters of the State Mineralogist's Report, XV Biennial Period, 1915-1916, Fletcher Hamilton:	
**Mines and Mineral Resources, Alpine, Inyo and Mono Counties, 176 pp., paper	----
Mines and Mineral Resources, Butte, Lassen, Modoc, Sutter and Tehama Counties, 91 pp., paper—Price $0.50, sales tax $0.01	.51

REPORTS—Continued

Asterisks (**) indicate the publication is out of print.

Price (including postage and sales tax)

Mines and Mineral Resources, El Dorado, Placer, Sacramento and Yuba Counties, 198 pp., paper—Price $0.75, sales tax $0.02 $0.77

Mines and Mineral Resources, Monterey, San Benito, San Luis Obispo, Santa Barbara and Ventura Counties, 183 pp., paper—Price $0.75, sales tax $0.02 .77

**Mines and Mineral Resources, Los Angeles, Orange and Riverside Counties, 136 pp., paper ----

**Mines and Mineral Resources, San Bernardino and Tulare Counties, 186 pp., paper ----

**Fifteenth Report of the State Mineralogist, for the Biennial Period 1915-1916, Fletcher Hamilton, 1917:
A General Report on the Mines and Mineral Resources of Alpine, Inyo, Mono, Butte, Lassen, Modoc, Sutter, Tehama, Placer, Sacramento, Yuba, Los Angeles, Orange, Riverside, San Benito, San Luis Obispo, Santa Barbara, Ventura, San Bernardino and Tulare Counties, 990 pp., 413 illustrations, cloth ----

Chapters of the State Geologist's Report XVI, Biennial Period, 1917-1918, Fletcher Hamilton:

Mines and Mineral Resources of Nevada County, 270 pp., paper—Price $1.00, sales tax $0.03 1.03

Mines and Mineral Resources of Plumas County, 188 pp., paper—Price $0.50, sales tax $0.01 .51

Mines and Mineral Resources of Sierra County, 144 pp., paper—Price $0.75, sales tax $0.02 .77

Seventeenth Report of the State Mineralogist, 1920, 'Mining in California during 1920,' Fletcher Hamilton; 562 pp., 71 illustrations, cloth—Price $2.50, sales tax $0.06 2.56

Eighteenth Report of the State Mineralogist, 1922, 'Mining in California,' Fletcher Hamilton. Chapters published monthly beginning with January, 1922:

**January, **February, **March, **April, May, June, July, August September, October, November, December, 1922—Price $0.30, sales tax $0.01 .31

Chapters of Nineteenth Report of the State Mineralogist, 'Mining in California,' Fletcher Hamilton and Lloyd L. Root. January, February, March, September, 1923—Price $0.30, sales tax $0.01 .31

Chapters of Twentieth Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly. January, April, July, October, 1924, per copy—Price $0.30, sales tax $0.01 .31

Chapters of Twenty-first Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:

January, 1925, Mines and Mineral Resources of Sacramento, Monterey and Orange Counties—Price $0.30, sales tax $0.01 .31

April, 1925, Mines and Mineral Resources of Calavaras, Merced, San Joaquin, Stanislaus and Ventura Counties—Price $0.30, sales tax $0.01 .31

**July, 1925, Mines and Mineral Resources of Del Norte, Humboldt and San Diego Counties ----

**October, 1925, Mines and Mineral Resources of Siskiyou, San Luis Obispo and Santa Barbara Counties ----

Chapters of Twenty-second Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:

**January, 1926, Mines and Mineral Resources of Trinity and Santa Cruz Counties ----

April, 1926, Mines and Mineral Resources of Shasta, San Benito and Imperial Counties—Price $0.30, sales tax $0.01 .31

July, 1926, Mines and Mineral Resources of Marin and Sonoma Counties Price $0.30, sales tax $0.01 .31

**October, 1926, Mines and Mineral Resources of El Dorado and Inyo Counties, also report on Minaret District, Madera County ----

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

Chapters of Twenty-third Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:

January, 1927, Mines and Mineral Resources of Contra Costa County; Santa Catalina Island——Price $0.30, sales tax $0.01 $0.31

April, 1927, Mines and Mineral Resources of Amador and Solano Counties Price $0.30, sales tax $0.01 .31

**July, 1927, Mines and Mineral Resources of Placer and Los Angeles Counties ——

October, 1927, Mines and Mineral Resources of Mono County—— Price $0.30, sales tax $0.01 .31

Chapters of Twenty-fourth Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:

January, 1928, Mines and Mineral Resources of Tuolumne County—— Price $0.30, sales tax $0.01 .31

April, 1928, Mines and Mineral Resources of Mariposa County—— Price $0.30, sales tax $0.01 .31

**July, 1928, Mines and Mineral Resources of Butte and Tehama Counties ——

October, 1928, Mines and Mineral Resources of Plumas and Madera Counties——Price $0.30, sales tax $0.01 .31

Chapters of Twenty-fifth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:

**January, 1929, Mines and Mineral Resources of Lassen, Modoc and Kern Counties; also on Special Placer Machines——

**April, 1929, Mines and Mineral Resources of Sierra, Napa, San Francisco and San Mateo Counties——

July, 1929, Mines and Mineral Resources of Colusa, Fresno and Lake Counties——Price $0.30, sales tax $0.01 .31

October, 1929, Mines and Mineral Resources of Glenn, Alameda, Mendocino and Riverside Counties——Price $0.30, sales tax $0.01 .31

Chapters of Twenty-sixth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:

January, 1930, Mines and Mineral Resources of Santa Clara County; also Barite in California——Price $0.40, sales tax $0.01 .41

**April, 1930, Mines and Mineral Resources of Nevada County; also Mineral Paint Materials in California——

**July, 1930, Mines and Mineral Resources of Yuba and San Bernardino Counties; also Commercial Grinding Plants in California——

October, 1930, Mines and Mineral Resources of Butte, Kings and Tulare Counties; also Geology of Southwestern Mono County (Preliminary) Price $0.40, sales tax $0.01 .41

Chapters of Twenty-seventh Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:

January, 1931. Preliminary Report of Economic Geology of the Shasta Quadrangle. Beryllium and Beryl. The New Tariff and Nonmetallic Products. Crystalline Talc. Decorative Effects in Concrete—— Price $0.40, sales tax $0.01 .41

April, 1931, Stratigraphy of the Kreyenhagen Shale. Diatoms and Silicoflagellates of the Kreyenhagen Shale. Foraminifera of the Kreyenhagen Shale. Geology of Santa Cruz Island—— Price $0.40, sales tax $0.01 .41

**July, 1931. (Yuba, San Bernardino.) Feldspar, Silica, Andalusite and Cyanide Deposits of California. Note on a Deposit of Andalusite in Mono County; its occurrence and chemical importance. Bill creating Trinity and Klamath River Fish and Game District and its effect upon mining ——

October, 1931. (Alpine.) Geology of the San Jacinto Quadrangle south of San Gorgonio Pass, California. Notes on Mining Activities in Inyo and Mono Counties in July, 1931——Price $0.40, sales tax $0.01 .41

Chapters of Twenty-eighth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:

REPORTS—Continued

Asterisks (**) indicate the publication is out of print.

Price (including postage and sales tax)

January, 1932, Economic Mineral Deposits of the San Jacinto Quadrangle. Geology and Physical Properties of Building Stone from Carmel Valley. Contributions to the Study of Sediments. Sediments of Monterey Bay. Sanbornite_____Price $0.40, sales tax $0.01 $0.41

**April, 1932. Elementary Placer Mining Methods and Gold Saving Devices. The Pan, Rocker and Sluice Box. Prospecting for Vein Deposits. Bibliography of Placer Mining_____ ----

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Plate 4

San Benito Quadrangle

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Geologic and Topographic Map

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